AN OVERVIEW OF THE NEW MEXICO URANIUM INDUSTRY

New Mexico Energy and Minerals Department

January 1979

STATE OF NEW MEXICO
ENERGY AND MINERALS DEPARTMENT
OFFICE OF THE SECRETARY

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M E M O R A N D U M

TO: Recipients of "An Overview of the New Mexico Uranium Industry"

FROM: Gary Carlson, Assistant Secretary of Energy and Minerals

DATE: February 16, 1979

SUBJECT: "An Overview of the New Mexico Uranium Industry"

Thank you for your interest in New Mexico's uranium activities. Attached is a copy of the report you requested entitled, "An Overview of the New Mexico Uranium Industry." This booklet was prepared by Betty L. Perkins of the New Mexico Energy and Minerals Department and became available for distribution today.

This publication is one of the most comprehensive reports of its kind ever prepared for New Mexico, and I hope it is of benefit to you. Additional copies of this booklet may be obtained for $5.00 each by contacting the Communications Bureau of our Department. If you feel further information might be helpful, please feel free to contact me.

An Overview of the New Mexico Uranium Industry

New Mexico Energy and Mineral Department

January 1979

BRUCE KING, GOVERNOR
State of New Mexico

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INTRODUCTION

This report represents an attempt to gather as much information on the New Mexico uranium industry as possible and place it in one booklet. In order to keep the booklet to a reasonable size, much of the information has been summarized. For more complete information, the reader should refer to the source materials listed at the end of each section.

While the author has tried to make the information as accurate as possible, new data, changes in uranium company and utility growth plans, new regulations and requirements, and the fact that companies in some cases regard information as proprietary should all be considered while reading this report. Having visited the uranium mines regularly in the last year and talked with company personnel, the author is impressed with the rapid changes in company plans which occur in the mining industry. In addition complete data is often hard to obtain. For example not all companies have water flow meters at their discharge points in order to determine mine water discharge rates. There appears to be a lack of tabulation of all data from monitoring wells, etc. Point source emissions are only now beginning to be seriously studied as well as radionuclide transport in the environment. A great deal more data is needed. If the reader detects inaccurate statements, he is urged to write the author so that changes can be made in any following reports.

This report would not have been possible without the help of all the uranium industry. Tours of each mine and mill site and tours underground were especially helpful. The author wishes to express her appreciation to all the many industry personnel who answered her questions and showed her the many interesting aspects of mining and milling.

The New Mexico uranium mining industry represents an important source of revenue and jobs for the State of New Mexico. It it hoped that this booklet will aid anyone interested in that industry to obtain a better understanding and appreciation of the production of uranium in New Mexico.

CHAPTER I

HISTORY

Despite its vital importance today, the uranium industry is a comparatively new industry not only in New Mexico but in the rest of the world as well. Although the existence of the atom was first surmised by the ancient Greeks, it wasn't until the twentieth century that man began to understand how atoms combine and break apart.

One of the most important features, man learned, was that energies involved in nuclear processes are about a million times larger than those in chemical reactions. Vast amounts of energy would be released if suitable nuclear reactions could be found. All of this came to fruitation in 1938 with the discovery that uranium could be induced to fission, and the Nuclear Age had begun.

Before the discovery of fission there were few known uses for uranium and the demand for it was very low. But the new fission process demonstrated that uranium could be used to produce large amounts of energy in a small amount of time, such as for an atom bomb. When the United States and its Allies began developing such a bomb during World War II, most of the uranium used in the early weapons was produced outside the United States.

Following the end of the war, demand for uranium increased. Not only were the United States and its Allies increasing their development of atomic weapons, but it also was found possible to utilize fission for "controlled" energy release. This "controlled" energy release could be used to produce steam to turn turbines for electrical power generation.

In response to the rapidly increasing demand for uranium for military and industrial purposes, the Federal Government took steps to encourage the domestic production of uranium. In the late 1940's and early 1950's, the government issued several circulars providing incentives for domestic uranium production. Federal purchasing stations also were established. The Federal incentives were successful in promoting the rapid expansion of uranium production in the United

States. Most of this activity was centered in the Rocky Mountain states of Colorado, Utah, Arizona, Wyoming and New Mexico.

Development in New Mexico

Uranium had been found in New Mexico for hundreds of years before uranium mining began in the state in the twentieth century. Ancient Indians, for instance, are believed to have used uranium ore as a paint and for ceremonial purposes. However, none of the occurrences were ever recorded. As a consequence, the possibility of uranium production in New Mexico was overlooked when the demand for uranium arose after the discovery of fission in 1938.

The first recorded discoveries of uranium in New Mexico stemmed from the mining of carnotite ore in extreme northwestern New Mexico. Since 1918, the Carrizo Mountains west of Shiprock had been known to contain vanadium-bearing carnotite ore and during the period from 1942 to 1944, carnotite ore was mined in the eastern Carrizos for the mineral's vanadium content.

Following World War II, the Federal uranium incentives resulted in the discovery of uranium deposits in the Sanostee area south of the Carrizo Mountains. At the same time, discoveries also were made in the Cuba-San Ysidro area lying on the eastern side of the San Juan Basin in north central New Mexico. Ironically, no significant discoveries were made in the area that was to become the most prolific uranium producing district in the world -- the Grants Mineral Belt. But this suddenly changed on one spring day in 1950.

Paddy Martinez, a Navajo sheepherder who liked to pick up unusual looking rocks, noticed a curious-looking yellow rock one day. He took the stone to Grants where it soon was determined to contain uranium -- the first recorded uranium discovery in the Grants Mineral Belt. The uranium occurred in a Todilto Limestone outcrop near Haystack Mountain, 15 miles northwest of Grants, on land belonging to the Santa Fe Railway. During the fall, Santa Fe mining engineer T. O. Evans examined the site. An exploration program was launched which resulted in the discovery of commercial deposits in the Todilto Limestone formation.

The exploration in the Todilto resulted in the development of the Haystack Mine. At the same time, the discoveries sparked immense interest in the Grants area by other mining companies. As a result, many prospectors became active in the area.

In January of 1951, T.O. Evans found uranium in the outcrop of the sandstone Morrison Formation in Poison Canyon just a short distance from the Haystack area. This deposit was developed as the Poison Canyon mine. This discovery also led to the delineation of the Poison Canyon trend deposits.

In November 1951 near Laguna, a radioactive anomaly was detected in an air survey by the Anaconda Company. By 1958, this "find" was to become the largest uranium mine in the United States.

In 1951 the Denver Exploration Branch of the Atomic Energy Commission did a reconnaisance mapping of the Jurassic outcrops from Grants to Gallup. The results were published in 1952, thus encouraging further exploration. By 1956, all surface occurrences in the region had been discovered.

Subsurface deposits were discovered in 1955 in the Morrison Formation north of Poison Canyon in the Ambrosia Lake area. This discovery received wide publicity and the resulting extensive subsurface drilling program has resulted in the development of several multi-million ton deposits, chiefly in the Westwater Member of the Morrison.

Drilling downdip from outcrops in the Morrison and Dakota Formations in the Gallup and Thoreau areas led to the discovery of ore bodies near Smith Lake and north of Church Rock in 1958.

Exploratory drilling has continued downdip in the Morrison. In 1966, the northeast Church Rock ore body was discovered. Drilling eastward has defined ore bodies in the Crownpoint area (see section on mines under development). Downdip and east from Ambrosia Lake, ore was discovered near San Mateo in 1968, and in 1969 ore was found at a depth of 4,000 feet on the western side of Mount Taylor. In the early 1970's, ore was also discovered on the eastern flank of Mount Taylor in the Morrison near Marquez. In August 1976, Continental announced a major find even further east on the Bernabe Montano Grant, and Kerr-McGee presently has a mine under development in this general region (northwest of Bernabe).

The areas which were found in the earlier years have continued to receive a great deal of interest in terms of exploration. For example, Exxon in 1974 signed an agreement with the Navajo Tribe to explore 400,000 acres of tribal land in the western San Juan Basin. Drilling is continuing near Cuba, and active exploration programs are underway at Crownpoint, Ambrosia Lake, Church Rock, etc. (See section on exploration). While some ores have been shipped out of state for processing, mills have been built in New Mexico to process most of the ore. (See section on mills).

Since the 1950's, uranium production has become one of the major industries of New Mexico. From 1948 through 1977, 59,850,000 tons of uranium ore containing 126,800 tons of U_3O_8 were shipped to mills from New Mexico mines. Purchases of New Mexico concentrate production by the Federal government are given in Table I-1, while Table I-2 shows yearly production of concentrate in New Mexico. Table I-3 lists ore receipts of ore shipped to mills for several recent years. As the table shows .81 million more tons of ore were received in 1977 than in 1976. This rapid increase in production will probably continue (See section on predicted uranium requirements and ore production).

The amount of ore received at the mill does not reflect the total amount of material removed from the mines. In 1977 for example, 4,209,000 tons of ore were received at the mills while 5,912,333 tons of material were removed from mines. This difference was due to the fact that (1) low grade uranium containing material (usually around .03-.05 percent U_3O_8) was either stockpiled or put on waste piles; (2) some barren waste rock was taken from mines as they were developed, and (3) some mines were stockpiling millable ore.

Table I-1

AEC Concentrate Purchases in New Mexico

Year	Tons of U_3O_8	Purchase Cost
1955	847	$ 19,978,000
1956	2,891	64,633,000
1957	2,534	50,920,000
1958	3,604	66,462,000
1959	6,772	112,770,000
1960	7,760	125,146,000
1961	7,750	123,794,000
1962	7,293	110,373,000
1963	5,512	85,892,000
1964	4,747	75,975,000
1965	4,591	73,464,000
1966	4,393	70,285,000
1967	4,698	75,147,000
1968	4,300	68,801,000
1969	4,104	47,150,000
1970	833	7,875,000
TOTAL	72,629	$1,178,665,000

Data taken from GJO-100(78) Statistical Data of the Uranium Industry

Table I-2

Uranium Concentrate Production in New Mexico

Year	Tons of U_3O_8	Per Cent of Total U.S. Production
1966	5,076	48
1967	5,933	53
1968	6,192	50
1969	5,943	51
1970	5,771	45
1971	5,305	43
1972	5,464	42
1973*	4,634	35
1974	4,951	43
1975	5,191	45
1976	6,059	48
1977	6,780	45
AVERAGE		46
AVERAGE EXCLUDING 1973		47

* - During this year, there was a prolonged labor strike at Kerr-McGee (one of the state's leading producers of uranium)

Data taken from GJO-100(78) Statistical Date of the Uranium Industry

Table I-3

Ore Weighed and Sampled by Mills and Buying Stations in New Mexico

Year	Tons of Ore	Tons of U_3O_8
1974	2,997,000	5,400
1975	2,985,000	5,500
1976	3,401,000	6,500
1977	4,209,000	7,600

Data taken from GJO-100(78), GJO-100(77), GJO-100(76) and GJO-100(75)

Source Material

Chapter I

1. Statistical Data of the Uranium Industry, GJO-100(78), Grand Junction Office, Department of Energy, Grand Junction, Colorado.

2. Chenoweth, William L., "Uranium in the San Juan Basin -- An Overview," Guidebook of San Juan Basin III, New Mexico Geological Society Twenty-Eighth Field Conference, September 15-17,1977.

3. Hilpert, Lowell S., "Uranium Resources of Northwestern New Mexico," Geological Survey Professional Paper 603, U.S. Printing Office, Washington, 1969.

4. Geology and Technology of the Grants Uranium Region, compiled by Vincent Kelley, Memoir 15, New Mexico Bureau of Mines and Mineral Resources, 1963.

5. Statistical Data of the Uranium Industry, GJO-100(77)

6. Statistical Data of the Uranium Industry, GJO-100(76)

7. Statistical Data of the Uranium Industry, GJO-100(75)

8. Personal communications with industry officials.

9. Uranium Exploration Activities in the United States, EPRIEA-401, June 1977, prepared by S.M. Stoller.

CHAPTER II

GEOLOGY AND URANIUM ORE CHARACTERISTICS OF THE SAN JUAN BASIN

Location

The roughly circular shaped San Juan Basin, which lies mainly in Northwest New Mexico, has been the source of more uranium production than any other area in the United States. The area will continue to be an important production center as slightly over half the nation's uranium reserves are located in this Basin.

While uranium has been found at other locations in New Mexico, that part of the San Juan Basin located in New Mexico is by far the most important uranium producing area in the State. Most of the uranium so far discovered in this Basin has been found in the Grants Mineral Region. This region (or Belt) may be defined (Figure II-1) as running west-east from Gallup to the Rio Puerco and extending north-south from Nose Rock to Grants.

Formations

The San Juan Basin is composed of about 0-10,000 feet of Paleozoic, Mesozoic, and some Tertiary sedimentary rock sequences which dip gently inward towards the center of the Basin (Figure II-2). This area was a region of alternate periods of marine and continental environments. The stratigraphic sequences from Pre-cambrian through Cretaceous age are shown in Figure II-3.

The uranium deposits delineated so far in the Basin occur in the Todilto Limestone, (though in a few places ore has been also mined from the underlying Entrada Sandstone), the Morrison Formation Sandstones, the Dakota Sandstone, and to a small extent the Mesa Verde Group. A small amount of ore has been produced from sandstone in the lower part of the Fruitland Formation northwest of Farmington. The Ojo Alamo and San Jose Formations contain uranium in Rio Arriba and San Juan counties, though no commercial deposits have been developed.

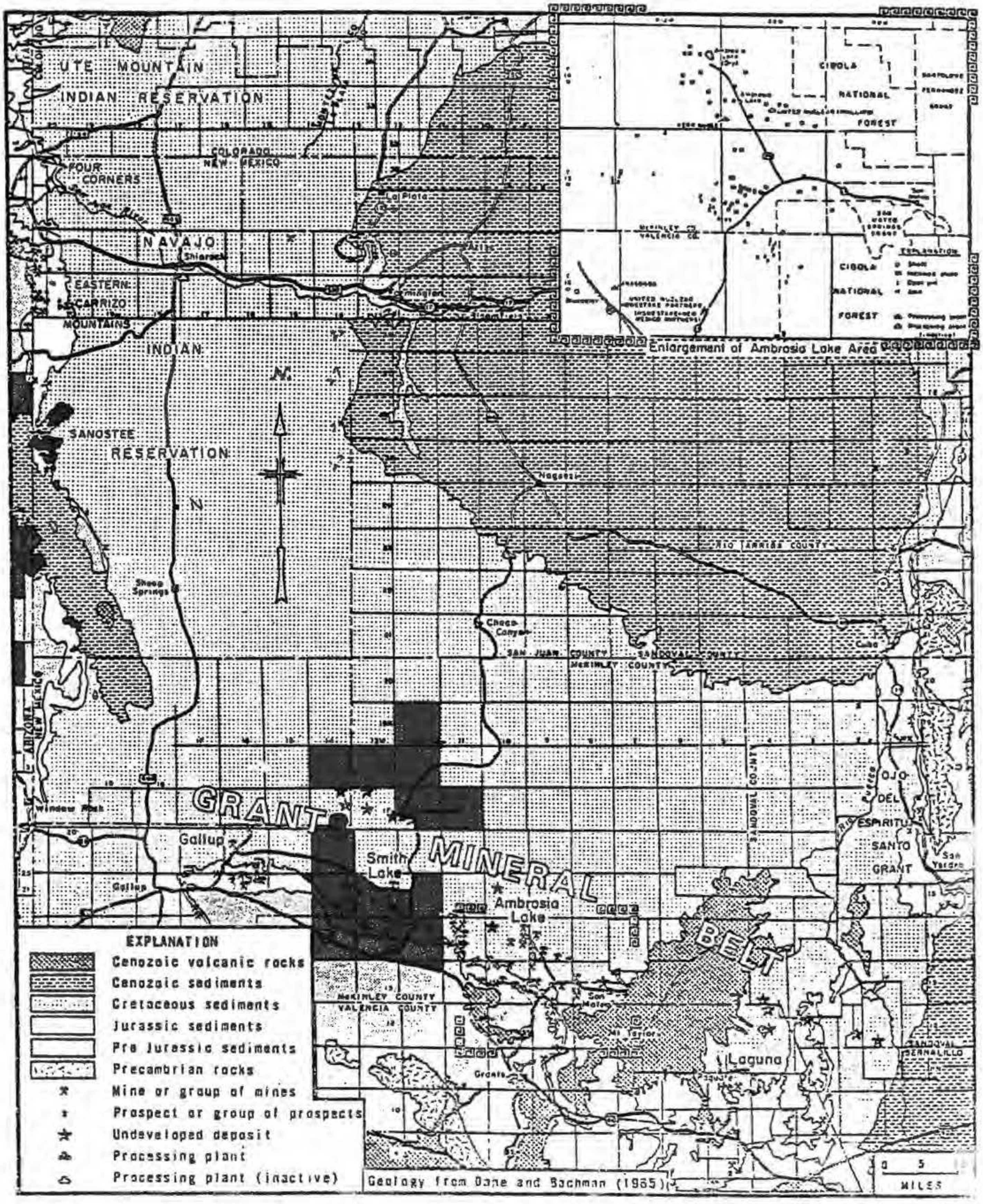
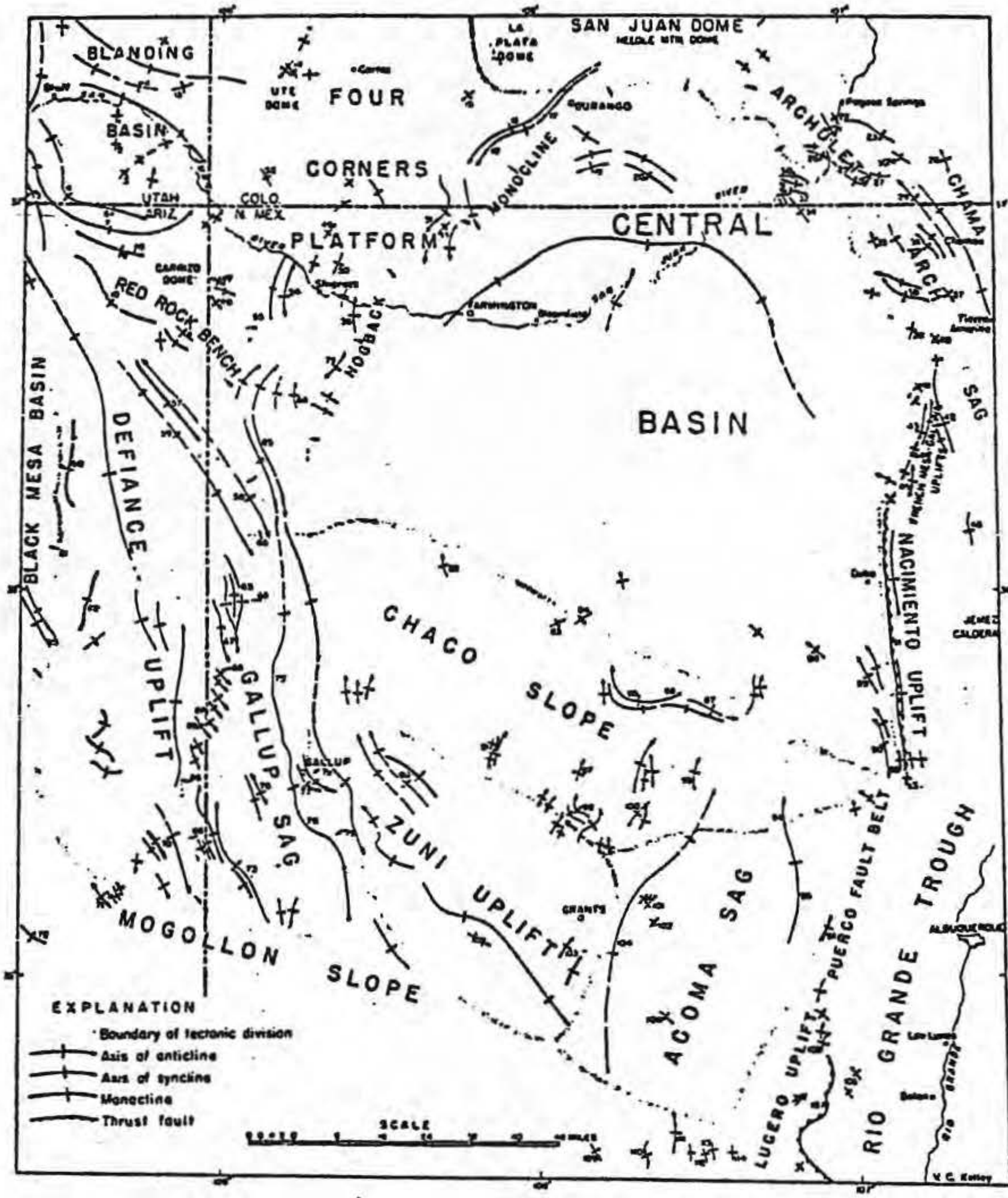


Figure II-1 Uranium occurrences, mines and mills, San Juan Basin.

Source: William Chenoweth, "Uranium in the San Juan Basin - An Overview"

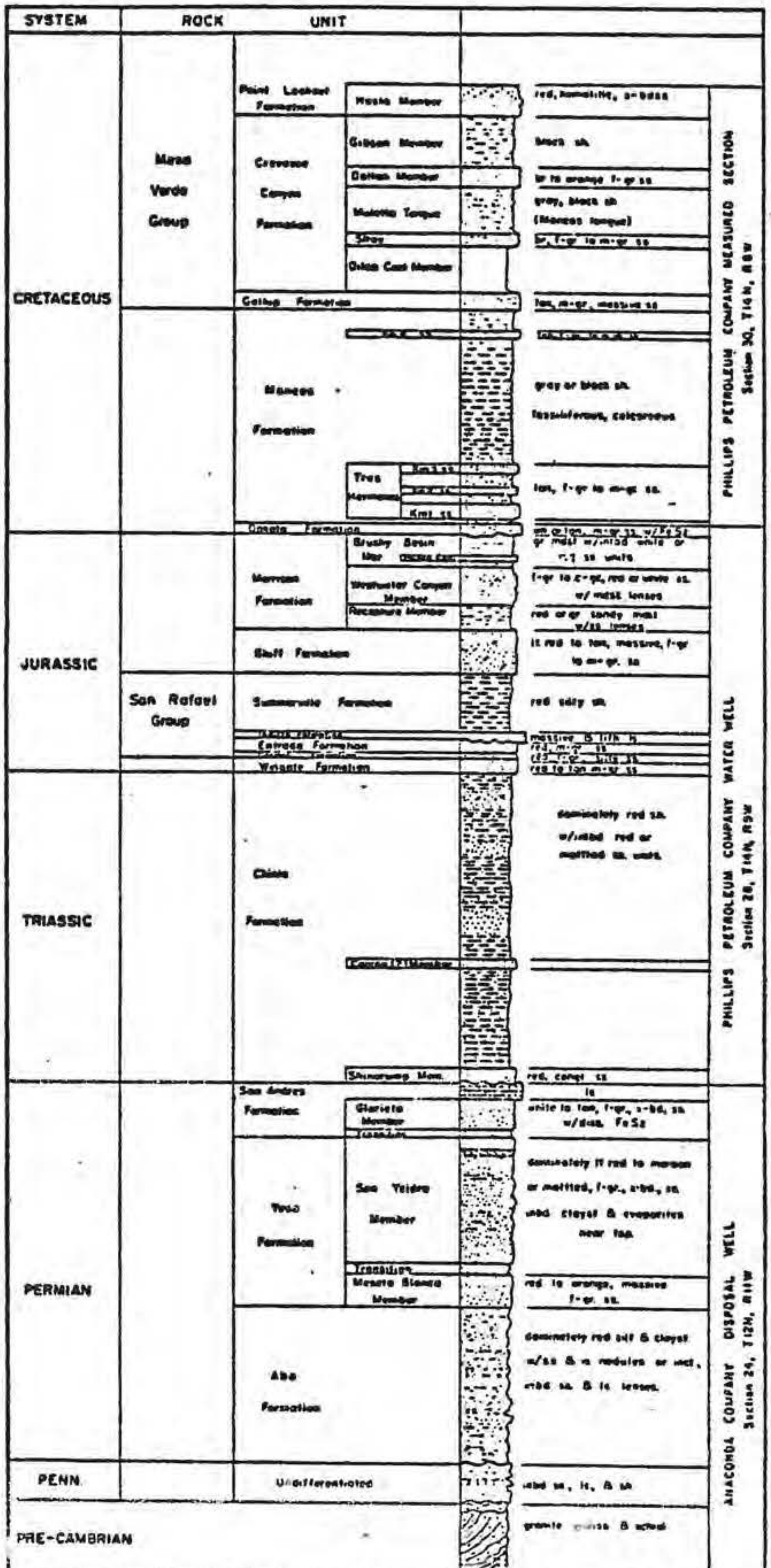
FIGURE II-2



TECTONIC MAP OF SAN JUAN BASIN AND ADJACENT AREAS

Source: Geology and Technology of the Grants Uranium Region Memoir 15

FIGURE II-3



COMPOSITE COLUMNAR SECTION SOUTHEASTERN AMBROSIA LAKE AREA

Source: Geology and Technology of the Grants Uranium Region Memoir 15

Most of the uranium has been produced from members of the Morrison Formation. Figure II-4 shows the ore bodies in the Morrison at Ambrosia Lake. Several bodies which have been developed as single mines in the Morrison contain more than 10 million pounds of U_3O_8. The Mount Taylor deposit of Gulf's has already been defined to contain more than 100 million pounds of U_3O_8 with development drilling still continuing.

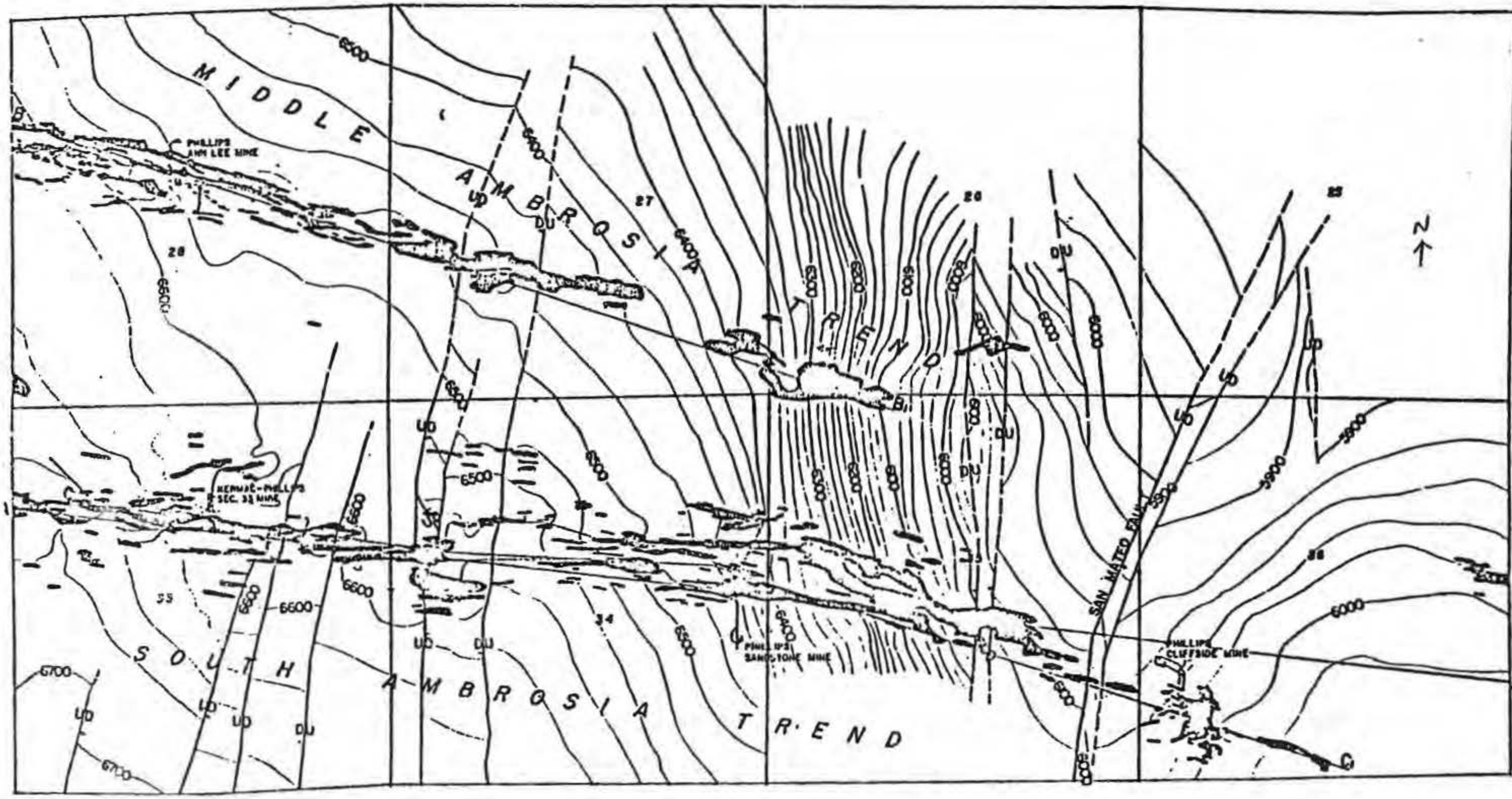
Ore Characteristics

In the Morrison Formation carbonaceous material and perhaps clays have probably acted to cause precipitation of the uranium from fluids which were moving through the sandstone. The ore bodies in the Morrison Formation occur in more or less two types. One type (referred to as primary) occurs as elongate discontinuous podlike masses up to many hundreds of feet wide and over a mile long. In general, the long dimension trends northwesterly. The thickness ranges from a few inches to 20 feet or more. The second type of deposit (called redistributed or stack ore) tends to be equant laterally, up to several hundred feet across, and with vertical thickness from a few tens of feet to more than 100 feet.

The ore bodies which have been developed so far have been mined to produce an average U_3O_8 ore grade of approximately .21%. However, as the price of U_3O_8 increases, lower grade ores will be processed. Figure II-5 is a histogram of assay values from an Ambrosia Lake deposit. It can be seen that mining of the lower grade ores is important if all the U_3O_8 is to be recovered, except in those cases where the ore has been concentrated into a fairly discrete body.

In general, the ores in the San Juan Basin are in secular equilibrium (the number of disintegrations per second for each member of the uranium decay series is the same). However, presently in the Church Rock area and at the Mariano Lake mine the ores are sometimes not in equilibrium. Recent redistribution of uranium has been observed in some of the mines in the Poison Canyon area so that secular equilibrium is not always present in this area.

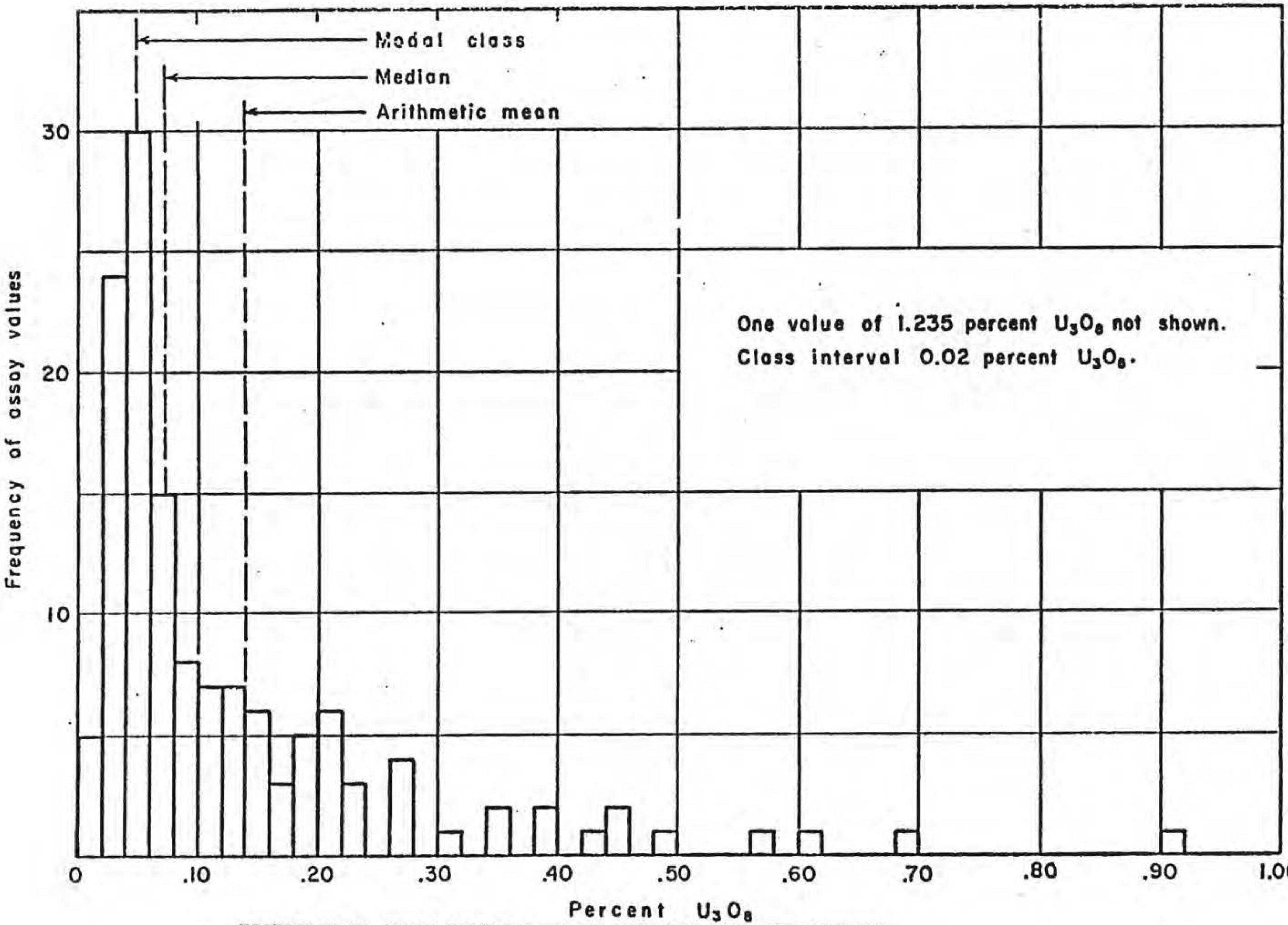
FIGURE II-4



ORE DISTRIBUTION AND STRUCTURE CONTOUR MAP OF THE SOUTHEASTERN AMBROSIA LAKE AREA

Source: Geology and Technology of the Grants Uranium Region, Memoir 15

FIGURE II-5



HISTOGRAM OF ASSAY VALUES FROM AN AMBROSIA LAKE ORE DEPOSIT

Source: Geology and Technology of the Grants Uranium Region, Memoir 15

Production

Table II-1 presents a summary of uranium production of ore from the San Juan Basin. The importance of production from the Morrison Formation is obvious. Both molybdenum and vanadium have been recovered as by-products from the uranium ore.

TABLE II-1

SUMMARY OF URANIUM PRODUCTION, SAN JUAN BASIN

Area and Source	Member	Number of Properties	Type of Mine	Years of Production	Production tons U_3O_8
Grants Mineral Belt					
Morrison Formation	Westwater, Brushy Basin minor Recapture	129	underground and pit	1951-present	114,795
Todilto Limestone		42	underground and pit	1951-present	2,718
Dakota Sandstone		9	underground	1951-1970	246
Mine Water				1963-present	1,145
Breccia Pipe		1	underground	1953-1956	67
East Carrizo Mts.					
Morrison	Salt Wash	45	underground	1948-1968	110
Sanostee					
Morrison	Recapture, minor Salt Wash	11	underground	1951-present	81
Todilto Limestone		2	pit	1954	
Nacimiento					
Morrison	Brushy Basin	2	pit	1950's	
Dakota Sandstone		1	pit	"	1
Farmington					
Fruitland		1	pit	1955	
			TOTAL		119,163

Source William Chenoweth, "Uranium in the San Juan Basin - An Overview"

Source Material

Chapter II

1. Statistical Data of the Uranium Industry, GJO-100(78), DOE, Grand Junction, Colorado.

2. Chenoweth, William L. "Uranium in the San Juan Basin - An Overview," Guidebook of San Juan Basin III, New Mexico Geological Society Twenty-Eighth Field Conference, September 15-17, 1977.

3. Chapman, Wood, and Griswold, Inc., "Geological Map of Grants Uranium Region", Geologic Map 31 rev., New Mexico Bureau of Mines and Mineral Resources, 1977.

4. Geology and Technology of the Grants Uranium Region, compiled by Vincent Kelley, Memoir 15, New Mexico Bureau of Mines and Mineral Resources, 1963.

5. Mill License Application - Mount Taylor Mill, 1978, Filed with New Mexico Department of Health and Environment.

6. Personal communication with personnel of Gulf Mineral Resources and Kerr-McGee.

CHAPTER III

RESERVES AND RESOURCES IN NEW MEXICO

RESERVES

Reserves as a Function of Forward Cost

For a number of years, the federal government at the Grand Junction Office has collected from uranium exploration companies drilling data on a confidential basis and from this data and other engineering data has compiled reserve estimates for uranium. The reserve estimates have traditionally been published as reserves in various "forward cost categories." By forward cost is meant the operating costs and those capital costs "not yet incurred." In the reserves published this year in GJO-100(78), the reserves were adjusted for mining dilution and recovery (but not mill recovery). Thus the federal government (DOE) published 1977 reserves in the $15, $30, and $50 cost categories represent the material that is estimated to be recoverable by mining at or less than those costs. Table III-1 gives the U_3O_8 reserves for New Mexico in the $15, $30, and $50 per pound categories, and includes for comparison total U.S. and world reserves (excluding China, USSR, and associated countries) in those classifications also.

TABLE III-1 URANIUM RESERVES
IN THOUSAND TONS U_3O_8

	$15	$30	$50
New Mexico	222	367.7	465.0
Total U.S.	370	690.0	890.0
% New Mexico of Total U.S.	60	53	52
World Reserves*		2,200	2,900
% New Mexico of World Reserves		17	16

*excluding China, USSR, and associated countries.

New Mexico has more reserves in the $50 per pound category than any one of the included foreign countries. Most of the additions to the U.S. $30 and $50 reserves in 1977 were due to increases in the reserves of the San Juan Basin in New Mexico, reflecting the results of intensive exploration in the past three years.

Ore Grade

To indicate the relationship of ore grade to forward costs Table III-2 has been included. This table also indicates that very few new deposits become available as the forward cost category increases from $30 to $50.

TABLE III-2 ORE GRADE AND NUMBER OF DEPOSITS FOR NEW MEXICO RESERVES 1/1/78

Forward Cost	Tons of Ore	% U_3O_8	No. of Deposits
$15	111,300,000	.20	106
$30	318,000,000	.12	174
$50	547,100,000	.09	177

The Grand Junction Office of DOE also publishes New Mexico $50 reserves as a function of grade and tons of ore vs. number of properties. This data is given in Table III-3. This table indicates that very few properties contain more than 10,000 tons U_3O_8.

TABLE III-3
NEW MEXICO 1/1/78 $50 RESERVES GIVEN AS NUMBER OF PROPERTIES WITHIN SELECTED RANGES OF GRADE AND TONNAGE

	Average Grade %U_3O_8			
Tons Ore (thousand)	0-.05	.05-.10	.10-.20	.20-.40
> 8,000	3	14	5	0
4,000-8,000	4	7	3	0
2,000-4,000	4	5	0	0
1,000-2,000	3	8	7	2
500-1,000	3	6	3	0
0- 500	4	78	16	2

Data Source: GJO-100(78)

The federal government has also begun to publish (in the GJO series), for New Mexico a pre-production uranium mineral inventory and a post-production uranium mineral inventory. The post-production inventory (Table III-4) reflects <u>in-place</u> distributions of U_3O_8 after subtracting all production prior to January 1, 1978. Included in this table is the percentage of total inventory contained in ore above or equal to the given minimum grade. The importance of low grade ores in relationship to the total in-place inventory can be seen from this table.

TABLE III-4

NEW MEXICO POST-PRODUCTION URANIUM MINERAL INVENTORY, 1/1/78

Minimum Grade % U_3O_8	Cumulative Tons of Ore (millions)	Ave. Grade % U_3O_8 of Cumulative Tons	Cumulative Tons U_3O_8 (thousands)	Percent of Total U_3O_8 $\geq$ Minimum Grade
.01	1,064	.05	580·	100
.02	793	.07	523	90
.03	572	.08	469	81
.04	425	.10	425	73
.05	325	.12	390	67
.06	253	.14	354	61
.07	200	.15	310	53
.08	159	.17	270	47
.09	131	.19	249	43
.10	114	.20	228	39
.11	101	.22	216	37
.12	90	.23	207	36
.13	80	.25	198	34
.14	72	.26	187	32
.15	65	.27	176	30
.16	59	.29	167	29
.17	53	.30	159	27
.18	49	.32	153	26
.19	44	.33	145	25
.20	41	.34	139	24
.21	38	.36	135	23
.22	35	.37	130	22
.23	32	.38	124	21
.24	30	.40	120	21
.25-over	28	.41	115	20

Data Source: GJO-100(78)

Land Status and Location

The New Mexico uranium reserves are located on private, public and Indian lands. Table III-5 shows the $50 reserves by land status. As can be seen only a small fraction of the reserves are on state land.

TABLE III-5

NEW MEXICO 1/1/78 $50 URANIUM RESERVES BY LAND STATUS

Land Status	Tons U_3O_8	%TOTAL
Private*	254,000	54
Federal	123,000	27
Indian	79,000	17
State	9,000	2

*Includes railroad lands

Data Source: Robert J. Meehan, Chief .
Ore Reserves Branch Resource Division
Department of Energy, Grand Junction Office

As of January 1, 1978 for the $50 forward cost reserves about 72% of New Mexico reserves were located in McKinley County, 23% in Valencia County, and 4% in Sandoval County.

Accuracy

A great many factors enter into the determination of the accuracy of reserve data including: (1) industry's willingness to accurately report drilling results, (2) assumptions made concerning ore grade distributions in an ore body, (3) accuracy of drill hole data, (4) non-uniformity of ore bodies, and (5) the breakdown by "forward cost category." Carl Appelin of the GJO office has indicated that the reserve numbers are believed to be accurate to ±20%.

RESOURCES

Definitions of Resources

The Grand Junction Office also tries to access resources of uranium. These resources have been recently defined into several classes. "Probable" potential resources are those estimates of uranium occurrence in known productive uranium districts in extensions of known deposits or in undiscovered deposits within known geologic trends or areas of mineralization. "Possible" potential resources are those estimated to occur in undiscovered or partly defined deposits in formations or geologic settings productive elsewhere within the same geologic province. "Speculative" potential resources are those estimated to occur in undiscovered or partly defined deposits in formations or geologic settings not previously productive within a productive geologic province or within a geologic province not previously productive.

Estimates of New Mexico Uranium Resources

Table III-6 lists the resource estimates for New Mexico and for the United States as a whole.

TABLE III-6

URANIUM RESOURCES OF \$50/LB IN TONS U_3O_8

Area	Probable	Possible	Speculative
New Mexico	443,000	590,000	23,000
United States	1,395,000	1,515,000	565,000

Source: Hetland and Grundy, "Potential Uranium Resources," October 1978.

Accuracy of Data

As is implied in their definitions, the accuracy of the resource numbers decreases from probable to speculative. However even in the probable category some knowledgeable geologists outside of GJO have expressed doubt over the amount of uranium which GJO lists as probable in the northwest quadrant of New Mexico. As with oil and gas, drilling is the only way of presently determining the actual occurrence of uranium; and hence resource numbers must always be regarded in this context.

Source Material

Chapter III

1. Statistical Data of the Uranium Industry, GJO-100(78), United States Department of Energy, Grand Junction Office, Grand Junction, Colorado.

2. Robert J. Meehan, Grand Junction Office.

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CHAPTER IV

THEORETICAL GROWTH PROJECTIONS FOR URANIUM PRODUCTION IN NEW MEXICO

Generating Capacity

With New Mexico having such a dominant position in both U.S. and world reserves, it would seem reasonable to assume that New Mexico will continue to play an important role in the world's production of U_3O_8. Since nuclear reactors are already on line and in advanced stages of construction throughout the world, unless these projects are immediately shut down, uranium production will have to expand considerably in the coming years just to meet the annual and initial fuel requirements for these reactors. Table IV-1 indicates for the U.S. the present status of nuclear power plants.

TABLE IV-1

REACTORS IN THE UNITED STATES ON LINE OR ORDERED
(as of June 15, 1978)

71 reactors with operating licenses	51,226	MWe
89 reactors with construction permits	96,924	"
4 reactors with limited work authorization	4,626	"
47 reactors on order	53,253	"
1 letter of intent/options	1,150	"
212 Total	207,179	MWe

Source: Nuclear Information, Atomic Industrial Forum Inc. No. 40

As can be seen, there appears to be at least 207 GWe (billion watts electric) of nuclear capacity which will be on line when the number of plants ordered are completed.

However, it is not certain just how many new plants will be ordered in the coming years. Predictions for nuclear generating capacity on line in the year 2000 have been reduced drastically in the last few years. The government's energy plan target of even 380-400 GWe on line may not be reached.

Additional Factors Influencing Demand

Factors other than total on line nuclear reactor electrical generating capacity also influence U.S. uranium needs on both the short and long term basis. These include (1) advance uranium delivery for enrichment requirements placed on utilities by the federal government, (2) amount of U-235 in the enrichment tails, (3) reprocessing of spent fuel, (4) efficiency of fuel utilization and type of fuel used in the nuclear reactor, (5) imports of uranium from foreign countries into the U.S., (6) exports of domestic uranium to foreign counties, and (7) on line operating performance of nuclear reactors.

Uranium as it is mined consists of two isotopes of uranium, uranium-235 and uranium-238. The uranium isotope 235 differs from 238 in the fact that the 238 has 3 more particles known as neutrons in its nucleus. However, it is the U-235 which is important as a fissionable material when utilizing low energy neutrons with their high cross sections. For the two types of reactors in general use in the U.S. today enrichment up to approximately 3% U-235 is necessary.

In natural uranium, the U-235 is only about .7% of the total; hence a great many enrichment steps are necessary between uranium mining and its use in a reactor. These steps include milling, conversion in refineries to UF_6, enrichment of the U-235 in the uranium, and fabrication.

At the moment, the U.S. Government controls the U-235 enrichment facilities in the U.S. Utilities have been required to deliver uranium for enrichment to the government in order to obtain slightly enriched uranium for use in reactors. The amount of uranium which the government requires in a "stockpile" situation clearly influences short term U_3O_8 requirements.

Of even greater importance for uranium demand, particularly in long term requirements, is the federal government's policy on tails assay. In the enrichment process in use today one gas stream through the enrichment plant becomes enriched in the U-235 isotope while the other stream becomes depleted in the U-235 isotope. Clearly more work is required to create a highly enriched stream of U-235 or a highly depleted stream of U-235. However, the greater the amount of U-235 left in the depleted stream the more uranium feed is needed to produce a given enriched product. Appendix I estimates U-235 in tails under the system which has been in operation. It is clear from the data given in this appendix that recovery of the U-235 in the tails would have a significant effect on supply-demand; particularly, which is unlikely, if recovery was achieved in a short period of time. Advanced enrichment processes undergoing development may be able to efficiently recover the U-235 from the depleted tails. More information on advanced isotope separation is given in Appendix II.

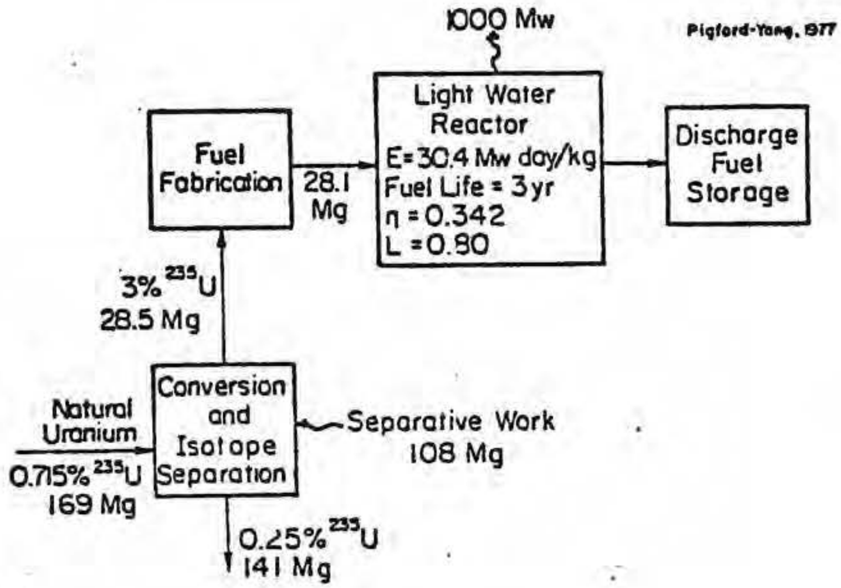
Since more work is required the greater the degree of separation between U-235 and U-238, for a given enrichment capacity, if more slightly enriched U-235 is needed the tails may also have to contain more U-235. Hence, increased enrichment demand may force an increase in U-235 in the tails and hence even more of an increase in feed requirements.

Since the present enrichment process is very energy intensive, if the energy is not available the tails assay of U-235 may also have to be increased. Currently the federal government is planning to upgrade the present enrichment facilities and to build a new centrifuge type facility (these actions are discussed more fully in Appendix II).

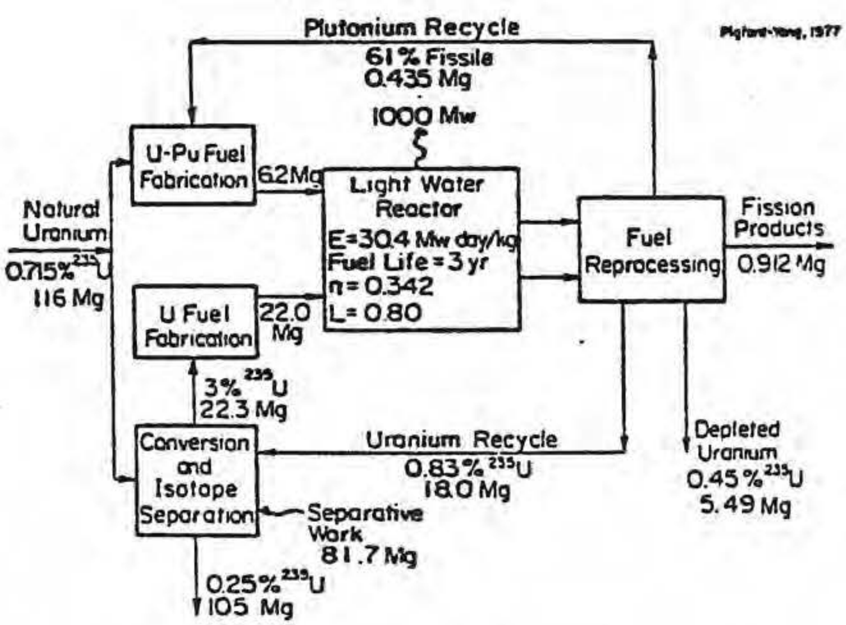
While not important on the short term basis, in assessing long term needs whether or not spent reactor fuel is reprocessed becomes an important consideration. Fuel that can no longer be used in a reactor and has to be removed still contains some U-235. In addition, some U-238 in the fuel has been converted into fissionable isotopes of plutonium. As compared with non-reprocessing for a pressurized water reactor, the long term effect of recycling both plutonium and uranium is to reduce the average consumption of natural uranium by 32%. In addition, because less uranium needs enrichment, the enrichment requirements (measured as separative work) are reduced by 24%. These two processes are compared in Figure IV-1.

Another aspect of fuel demand is the type of fuel used and the efficiency of conversion of the fuel into electrical energy. While light water reactors are chiefly in use today utilizing low energy neutrons with U-235 as the primary fuel (with some fission of Pu as U-238 converts) and running with certain fuel use efficiencies, other types of reactors are under consideration. For example, thorium-232

FIGURE IV-1



Material flowsheet for pressurized water reactor, no reprocessing.



Material flowsheet for pressurized water reactor with self-generated U-Pu recycle.

Source: Reviews of Modern Physics, January, 1978.

can be converted into U-233 which is a fissionable material. In theory, with a thorium system utilizing low energy neutrons, it is possible to make more fissionable material than is "used up"; hence the thorium system can be used as a breeder. Several considerations, however, would tend to "in theory" favor use of higher energy neutrons in a U-238 to plutonium conversion system if fuel is to be produced. However, in any type of breeder, the spent material must be separated from the fissionable material and hence reprocessing is necessary. Development of the breeder would give an increase in uranium utilization of roughly one-hundred fold. While even rapid development of the breeder will not effect very near term demands for uranium, it will have an extremely important role in long term uranium needs (see source material 4). More information on various types of reactors, fuel usage etc., is available in source material 2.

Another consideration in uranium demand is the amount of uranium imported from foreign countries. While New Mexico has more uranium reserves in the \$50/lb. category than any one free world foreign country, uranium is found throughout the world, and total foreign reserves excluding China, USSR, and associated countries in the \$50/lb. forward cost category exceed domestic reserves by a factor of 2.3. Countries which are uranium producers include Canada, South and S.W. Africa, Niger, Algeria, Gabon, France, and Australia.

A Canadian-American Committee of the National Planning Association has completed a study ("Uranium, Nuclear Power, and Canada-United States Energy Relations") which concludes that Canada could supply any shortfall in domestic U.S. supplies in the 1980's. However, the Canadian government has a great deal of control over uranium production and export, and the government's regulations will clearly influence U.S. import. Moreover, U.S. users were prohibted from entering the Canadian market by the U.S. embargo. Canadian uranium output is expected at 13,750 tons by 1984.

It was recently announced that Earth Sciences, Inc. has signed a contract to supply two U.S. Eastern utility companies with about 2 million pounds of U_3O_8 produced in Calgary, Alberta.

In addition to exports from Canada, Australian exports may also become important as Australia has the largest amount of uncommitted reserves. However, here again, the Australian government's uranium production policy, demands made by the aborigines, other foreign country's buying (such as Japan) of Australian output, etc., may limit exports to the U.S. The countries of South Africa will also play an important role in supplying the world with uranium. Table IV-2 indicates present uranium delivery commitments.

The U.S. also sells uranium to foreign countries. In New Mexico, Canadian companies including Dennison, New Cinch, and Noranda are active and may bring mines into production. It is not known whether this output will go to the Canadian market or not. Table IV-3 indicates U_3O_8 sales to foreign countries.

Uranium demand is also dependent upon how much of the time the reactors are on line. Obviously more uranium is needed for 92% on line generation time than for 60%. Reactors should become more reliable in the coming years and hence may require more uranium per installed MW than is presently required.

While the discussion of the uranium supply needs has been brief for such a complex subject, it is obvious that prediction of uranium requirements is very complex and cannot be made with any great accuracy since government policies, utility buying plans, etc. are constantly changing. Various uranium supply requirement scenarios, each made by a different agency of the government, are shown in Figure IV-2.

New Mexico Production Forecast

In order to give some indication of possible uranium production demand in New Mexico the following procedure was taken: (1) the forecast of domestic uranium requirements as published by the government in GJO-100(78) "Statistical Data of the Uranium Industry," was used (this forecast assumes no recycle, .20% tails to October 1980 and .25% tails thereafter and is included in Figure IV-2 as DOE contracts), (2) New Mexico was assumed to supply 47% of the domestic requirements, thus assuming no net foreign imports and a continuation of New Mexico's historical supply record, (3) the ore grade was assumed to slowly drop from year to year from .18 to .12% U_3O_8. These calculations are shown in Table IV-4.

According to this scenario almost half the $50 reserves would be depleted by 1990. Assuming no loss due to mining higher grade ores

TABLE IV-2

DOMESTIC U_3O_8 PROCUREMENT FROM FOREIGN SOURCES

Uranium delivery commitments, imports for domestic end use. As of January 1, 1978, U.S. companies have made purchase commitments for foreign U_3O_8 as follows. Some of this material may be reexported to foreign countries.

Year of Delivery	Tons U_3O_8	Tons U_3O_8 Cumulative
1975	700	700
1976	1,800	2,500
1977	2,800	5,300
1978	1,600	6,900
1979.	1,600	8,500
1980	2,700	11,200
1981	3,600	14,800
1982	3,600	18,400
1983	3,300	21,700
1984	3,100	24,800
1985	2,900	27,700
1986-90 Total	8,700	36,400

Note: The above figures include 2,600 tons of optional purchases. Reductions from January 1, 1977 totals represent uranium that has been reexported or is committed to be reexported, plus material that is under litigation.

Source: GJO-100(78)

TABLE IV-3

U_3O_8 SALES TO FOREIGN COUNTRIES

As of January 1, 1978, sales of domestic-origin U_3O_8 to foreign countries were scheduled as follows:

Year of Delivery	Tons U_3O_8	Tons U_3O_8 Cumulative
1966	400	400
1967	700	1,100
1968	800	1,900
1969	500	2,400
1970	2,100	4,500
1971	200	4,700
1972	100	4,800
1973	600	5,400
1974	1,500	6,900
1975	500	7,400
1976	600	8,000
1977	2,000	10,000
1978	1,500	11,500
1979	1,400	12,900
1980	1,000	13,900
1981	400	14,300
1982-88 Total	1,200	15,500

Source: GJO-100(78)

TABLE IV-4

POSSIBLE DEMAND FOR NEW MEXICO URANIUM

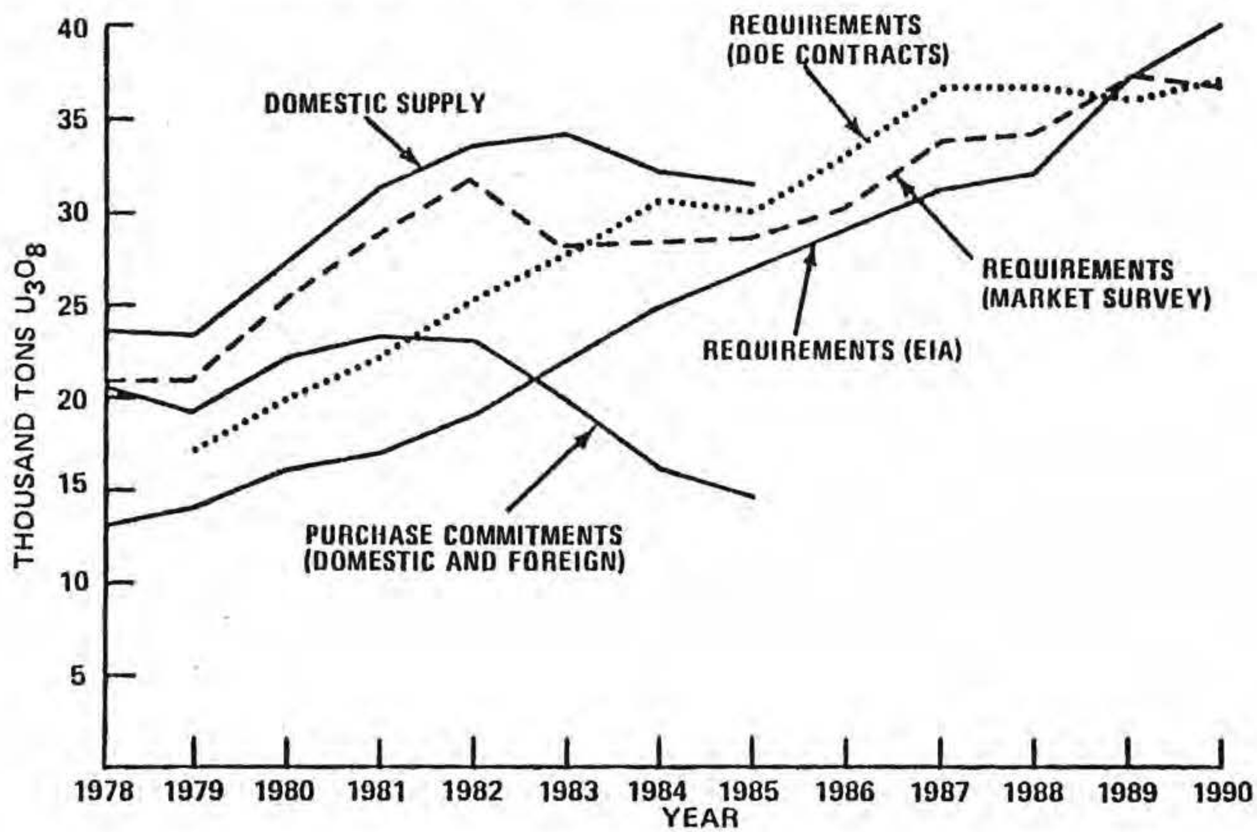
Year	Forecast U.S. Domestic U_3O_8 Requirements (tons)	Assumed New Mexico U_3O_8 Demand (tons)	Assumed Grade %	Assumed+ Mill Recovery	New Mexico* Ore Production (thousand tons)
1978	18,600	8,742	.18	.91	5,337
1979	21,200	9,964	.18	.91	6,083
1980	28,100	13,207	.17	.91	8,537
1981	31,200	14,664	.17	.91	9,479
1982	33,300	15,651	.16	.91	10,749
1983	34,900	16,403	.16	.91	11,266
1984	40,300	18,941	.15	.91	13,876
1985	41,100	19,317	.15	.91	14,152
1986	43,000	20,210	.14	.91	15,863
1987	44,600	20,962	.14	.91	16,454
1988	44,500	20,915	.13	.91	17,680
1989	44,700	21,009	.13	.91	17,759
1990	45,600	21,432	.12	.91	19,626
TOTAL	471,000	221,417			

*Ignores contributions from in-situ leaching and uranium recovery from mine waters.

+Present recovery is assumed to continue despite dropping ore grade due to more efficient mills coming on line.

FIGURE IV-2

DOMESTIC URANIUM SUPPLY VS. REQUIREMENTS



Source: Combs and Patterson, "Uranium Market Activity" only, a U_3O_8 production average of 25,000 tons for the next 10 years would lead to the depletion of all the New Mexico $50 forward cost reserves by the year 2000.

While New Mexico's ore production is somewhat dependent upon the ore grade and mill recovery assumptions, it would appear that the New Mexico uranium industry may need to increase present mine production by a factor of at least four by 1990 if domestic requirements are to be met. The ore grade mined will be highly dependent upon the selling price of uranium vs. costs of recovery down to very low grade cut-offs. (Present indications are that for many of the mines presently being opened cut-off will run as low as .05-.07% U_3O_8).

Actual Uranium Ore Production

Whether or not New Mexico uranium producers will be able to bring uranium production on line to meet demands is dependent upon many factors including the availability of financing, the selling price of U_3O_8 vs. production costs, leasing policies adopted by the Indians, state and federal taxes and regulations, manpower supply, necessary development lead times, and electric and liquid fuel availability. Short term industry plans for opening new mines are discussed in Section VI.

Several general studies of supply vs. demand have been made. For example in their latest GJO report (GJO-100(78)) the DOE Grand Junction office has published data on what they believe production capability to be. For 1980, they list a total U.S. capacity of 26,900 tons U_3O_8 and for 1985 a capacity of 39,500 tons U_3O_8. This production might result in some shortfall of domestic supply vs. demand. New Mexico production centers listed by GJO for New Mexico, which could be built in the coming years, include Gulf at San Mateo and perhaps another Mount Taylor facility, a facility at Crownpoint, the Phillip's facility at Nose Rock, perhaps a facility at Shiprock, and a facility near the Bernabe area.

More details on projected mines and mills in New Mexico are given in Sections VI and VII.

Source Material

Chapter IV

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13. "No Early Feed for AFC, Tails Option for LTFC," Nuclear News, August 1978, Vol. 21, No. 10.

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21. Statement of Dr. George W. Cunningham, Director, Division of Waste Management, Production and Reprocessing, before the Subcommittee on Fossil and Nuclear Energy Research, Development and Demonstration Committee on Science and Technology, U.S. House of Representatives, February 1977.

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23. Foreign Uranium Supply, prepared by the NUS Corporation for Electric Power Research Institute, Palo Alto, California, April, 1978, EPRI EA-725.

CHAPTER V

EXPLORATION BY THE URANIUM INDUSTRY

General Considerations

Historically, exploration techniques have included radiometric surveys from the air and ground, sinking of test pits, trenching, rim stripping by bulldozers and use of wagon drills. Evidences of early exploration surface disturbing activities can be seen throughout the Grants-Ambrosia Lake area.

Since all surface outcrops of uranium ore have probably been discovered, the exploration effort today is concentrated on detecting below surface deposits, with the Westwater Formation usually being the target. However, some "wildcat" type of exploration is being undertaken including areas outside the San Juan Basin. Drilling is the only technique which can be used to determine the actual occurrence of ore bodies below the earth's surface.

Drilling rigs vary in size and type. Since some drilling is being conducted at depths as deep as 4,700 feet, rigs capable of deep penetration are necessary. Nearly all of the drilling is by truck-mounted rotary rigs capable of drilling 5 3/4 or 7 7/8 inch diameter holes. The upper part of the hole may be drilled by air as far as possible and the remainder of the hole drilled by water and mud. A tri-cone rock bit is used for drilling.

The rig operator may lay out on the ground, near the rig, drill cuttings (one line of small piles representing 100 feet) taken at every so many feet (usually 5 feet). Then the staff geologist analyses these and if desired interesting portions are sent to the laboratory for further analysis.

Once the hole is drilled, it is logged. Usually this includes gamma ray measurement, resistivity, and self-potential curves as a function of depth. It has been reported that the present gamma ray instruments can delineate anomalous mineralization down to about 10-15 ppm of ${}_{e}U_3O_8$. Most ores in the Grants area are in secular equilibrium and hence the gamma detection system works well (though there are some anomalous areas). Ore holes may also be surveyed for drift. It is not uncommon for holes 2,500 feet deep to drift 100-400 feet or more. If water is encountered, the hole must be plugged in accordance with state regulations.

Exploratory drill holes are located quite far apart: ½ mile to several miles. Once mineralization is detected or looks favorable drilling is done at a closer interval. If these results look encouraging very close development drilling is performed (in some cases for fairly shallow bodies every 12½ feet). This close spaced drilling is necessary as the ore bodies are often very irregular and may even form rolls. However, close spaced drilling will not always accurately determine size, grade, location, etc. of an ore body. As mentioned previously, drilling holes are not straight, and the ore body may be very irregular. Hence it is usual once a mine is opened to drill from the development or haulage drifts (long-hole drilling) in order to more accurately delineate the ore body (these drill holes also serve to drain the ore body in wet mines).

Land Holdings

Table V-1 indicates the land held for uranium exploration and mining from 1974-1978.

TABLE V-1

LAND HELD FOR URANIUM EXPLORATION AND MINING IN NEW MEXICO

Date	Thousand Acres	Percent of Total U.S.
1/1/74	3,158	17
1/1/75	3,378	16
1/1/76	3,663	16
1/1/77	3,885	14
1/1/78	3,855	13

Source: GJO-100(78)

As can be seen the amount of land held in New Mexico has increased very little in the last five years, and percentage-wise for the total U.S. New Mexico's position for land holding has dropped. This is probably because interest has continued to be in the San Juan Basin area (see Table V-3), with the Westwater Formation receiving most of the target drilling. Since, as was described in the section on history, the occurrence of uranium in the San Juan Basin has been known for several years most of the available areas of interest have already been obtained.

Surface Drilling

In 1977, 41 million feet of hole were drilled in the U.S. for uranium exploration and development (expenditure data indicates 45.58 million feet). Areas of drilling interest included shallow low grade deposits in Wyoming, and areas in Texas, Utah, Colorado (where a new discovery had been recently made), and western Arizona. Table V-2 indicates drilling in New Mexico in the past few years and indicates the percent of total U.S. drilling this has represented. As can be seen, 1976 was an important year for drilling in New Mexico. The activity led to an increase in the state's reserves.

TABLE V-2

DRILLING IN NEW MEXICO FOR URANIUM
EXPLORATION AND DEVELOPMENT

Year	Thousands Feet	Percent of Total Drilling in U.S.
1975	5,698	21.9
1976	11,020	32.4
1977	9,100*	22.2

*The Grand Junction Office believes this number to be too low by about 1,000,000 feet. It is believed that a more accurate number is 10,500,000. It is also felt that the U.S. total is too low by about 4 million feet. These "corrected" figures would give New Mexico 23% of the total drilled.

Table V-3 shows a breakdown of the uncorrected numbers for surface drilling in New Mexico. As was mentioned, the staff at the DOE Grand Junction office believes drill hole footage to be too low in New Mexico by about 1 million feet.

As can be seen, McKinley, Sandoval, San Juan and Valencia counties, the counties in which most of the San Juan Basin is located, continue to be the important counties for drilling.

TABLE V-3

SURFACE DRILLING FOR URANIUM IN NEW MEXICO IN 1977

County	EXPLORATION			DEVELOPMENT		
	No. of Holes	Footage	Average Depth (ft.)	No. of Holes	Footage	Average Depth
McKinley	2,867	2,677,001	934	2,253	4,959,795	2,201
Sandoval	186	127,357	685	500	631,511	1,263
San Juan	125	237,550	1,900	-	-	-
Valencia	71	153,733	2,165	105	66,433	633
Others*	263	108,290	412	43	51,635	1,201
TOTALS	3,512	3,303,931		2,901	5,709,374	

*Bernalillo, Catron, Grant, Quay, Rio Arriba, Sierra, and Socorro

(source: William L. Chenoweth, Staff Geologist, Resource Division, DOE Grand Junction Office)

Of particular interest is the fact that in the "wildcat" type areas, 43 development drill holes were drilled. This indicates that an ore body or bodies has apparently been detected in this area at a fairly deep depth.

Drilling outside the San Juan Basin has been in progress near Quemado. The target here is the Baca Formation. Drilling has also been done in the basin to the east of Socorro and in the Hagan Basin near Albuquerque. Areas near Pecos have received some attention.

In New Mexico, 6,413 drill holes for a total of 9,013,305 feet have been reported by the industry. This averages out to 1,405 as the average depth of hole. If the extra 1 million feet which is believed by GJO to have been drilled also averaged 1,405 feet per hole, another 712 drill holes were probably drilled in the state, giving a total of 7,125 drill holes drilled in New Mexico in 1977.

Employment

Table V-4 gives employment of various types of people engaged in exploration activities in the state.

Expenditures

It is difficult to get area by area data on expenditures for land acquisition, exploration, and development since the Grand Junction Office does not collect the data in this type of breakdown.

In the data on expenditures reported by GJO, 45.6 million feet were reported drilled in the U.S. Excluding land acquisition, companies reported spending $229,860,000 on exploration activities. This then would make expenditures averaging $5.04 a drilled foot. If 10,500,000 feet were drilled in 1977, then uranium companies probably put about $52.9 million dollars into exploration in New Mexico in 1977. This may be too low an estimate as drilling in New Mexico is often to deeper depths than is the average elsewhere; deep drilling is expensive and adds to exploration costs. In addition, no expenditures were included for land acquisition.

TABLE V-4

1977 EMPLOYMENT IN EXPLORATION AND DEVELOPMENT

Type Service	Number
Geologist & Engineers	223
Drilling Services	418
Logging Services	85
Aerial Services	3
Others (such as landmen, surveyors, draftsmen)	260
TOTAL	989

(source: William L. Chenoweth, DOE Grand Junction Office)

Companies

Companies active in exploration and development in New Mexico in the last year include:

1. Kerr-McGee - drilling in the area of their Church Rock #1 and Church Rock #2 and the Roca Honda area near San Mateo.
2. UNC - drilling at the old Church Rock mine site, and Dalton Pass.
3. Teton - drilling close to old Church Rock mine, in Ambrosia Lake, near San Mateo, near Seboyeta and in the Crownpoint area.
4. Uranium King - drilling near Springstead.
5. Ranchers - drilling near Pinedale north of Prewitt, in Poison Canyon and near Datil.
6. Mobil - drilling in Crownpoint area.
7. Phillips - continuing drilling at Nose Rock.
8. Rocky Mountain - drilling south of Seven Lakes.
9. Keradamex - drilling south of Hospah and at El Rito.
10. Frontier - drilling south of Hospah and at El Rito.
11. Gulf Oil - drilling near Ambrosia Lake, San Mateo, Datil and Cabezon Peak.
12. Energy Fuels - drilling near Mesa Redonda and Evelyn mine.
13. Bokum Resources - continuing drilling at Marquez.
14. Sohio - continuing drilling at L-Bar Ranch.
15. Anaconda - drilling near their mine at Paguate, and near Placitas.
16. Conoco - drilling south of Seven Lakes, and east of San Mateo.
17. Exxon - drilling in the Sanostee area, near the L-Bar Ranch, near Cuba, and near Tucumcari.
18. Cobb - drilling northeast Thoreau and near Ambrosia Lake.
19. Todilto - drilling in the Haystack area.
20. Homestake - drilling near Poison Canyon and Rio Puerco.
21. Pioneer Nuclear - drilling northeast of San Mateo, at Seven Lakes and near Chaco Canyon.

22. Union Carbide - drilling in the Hagan Basin.

23. Koppen - drilling south of the Kerr-McGee mill.

24. Hydro-Nuclear - drilling near Ambrosia Lake.

25. Lucky Mt. - drilling at West Largo.

26. Noranda - drilling near San Mateo.

27. Reserve Oil and Minerals - drilling near Poison Canyon and in Valencia County.

28. UN-HP - drilling near Ambrosia Lake.

Other companies that may be active in exploration in New Mexico include Uranium Exploration Company, Anschutz, Ashland, Dennison, New Cinch, Farris Mines, Pathfinder, Mine X, High Peak Nuclear Mining Company, Western Nuclear, and Leonard Resources. An agreement to explore for uranium in 63,000 acres in the northwest portion of New Mexico has been entered into by Getty Oil Company of Los Angeles and the Mitsubishi Oil Company of Tokyo. This acreage is composed of federal mining claims and State of New Mexico mining leases.

Resource Requirements

The amount of fuel necessary to drill holes depends upon the types of rock drilled and the depth. Very little data is presently available to the state concerning energy use by drill rigs. One operator who reported drilling many feet at various depths (down to below 4,000 feet) reported average diesel fuel consumption of .9 gallon a foot. Using this number an estimate of 9,450,000 gallons of diesel fuel consumed can be obtained for drilling in New Mexico in 1977.

In addition to fuel used in drilling, fuel use should also include fuel used in equipment for road construction, drilling pad preparation, and transportation of the drilling rig and materials to the drilling location (including worker transport).

Other resource use includes mud and water needed for drilling and for well plugging. One operator drilling at depths of 3000-4000 feet reports waters needs as 8500 gallons per hole for drilling fluid and 420 gallons per hole for cement.

Environmental Considerations

Drilling rigs are noisy. Though rigs are many times away from heavily human populated areas, the activity probably disturbs animals and causes their movement to other locations.

Drilling rigs also emit NO_x, CO, SO_2, and organics. These pollutants will disperse, and since the areas rigs are located in usually have extremely good air quality, it would not be expected that air emissions from rigs would cause ambient air quality standards to be exceeded. However, truck movement over dirt roads will cause a high concentration of particulate in the immediate area which may cause the standard for particulates to be exceeded in these areas. Dust falling on plants will affect their ability to grow. The general activity of truck movement will in some cases cause animals to relocate. A few animals will probably be killed on the roads by passing vehicles.

Perhaps one of the most serious problems of drilling is land disruption. Drill rigs require about 1/3-1/4 of an acre for their pad. On grassy flat terrain a drill rig may cause no more damage than matting down of the grass and compaction of the soil. While grass does not grow as well afterward for some time, major erosion has not been observed by this author in these areas. However, at times drilling is in areas of pinyon and juniper cover or in steep terrain. Access roads have to be bladed in. The pinyon and juniper are uprooted. Flat, barren drill pads have to be prepared. In these cases, it appears to take some years for vegetation to become re-established. There may be problems with erosion, flash flooding, and loss of productive grazing land. Recharge to groundwater may be reduced. The barren areas may become a source of dust during the dry windy springs. Dust deposited on plants further damages vegetation.

Some companies are breaking up the hard soil where drill roads and pads have been and are reseeding with native seeds. Most companies are cleaning up and covering mud pits. However, some companies fail to take measures to reclaim as much as possible the disturbed area.

If it is assumed that ¼ of the drill holes are in disturbed terrain in which remedial measures are not taken, then approximately 588 acres of highly disturbed land were created due to drilling pads alone in 1977. If it is assumed that it takes an acre of access road per drill site and that again either 3/4 of the roads were (1) on flat grass land and were not bladed or were revegetated or (2) were in pinyon, juniper or rugged terrain but were revegetated, it can be seen that in 1977 approximately 1,781 acres of highly disturbed land may have resulted from construction of access roads.

Field investigations indicate that little has been done to restore the land surface where pits were dug and the land was stripped and trenched during very early exploration activities in the 1950's and early 1960's.

If drill holes are not plugged in accordance with state regulations, then interaquifer connections are possible. This can contaminate an aquifer having good quality water if the connecting aquifer has poor quality water.

Source Material

Chapter V

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3. Personal communication William L. Chenoweth, Grand Junction Office, Grand Junction, Colorado.

4. New Mexico Uranium Newsletter, Evelyn Saucier, Box 675, Cedar Crest, New Mexico.

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6. Personal communications USGS and Staff of Mobil Oil.

7. On site field visits.

8. Bernabe EA filed with USGS.

9. "Area Nuclear Exploration at Peak," Santa Fe Reporter, April 6, 1976.

10. Nuclear News, December 1978, Vol. 21 No. 15, p. 36.

11. Water Rights application to the State of New Mexico by Phillips Petroleum Co.

CHAPTER VI

MINING

Techniques

The first areas, in general, to be mined for uranium in New Mexico were the easily discovered ores near the surface and in outcrops. For deposits 60 feet or less below ground the barren surface material was removed. The ore removal was either in a typical pit type operation or in some cases channels which followed the ore body were excavated. If the ore body moved deeper off the pit area, adits in some cases were constructed to recover the ore. Outcrops and fairly shallow ore bodies too deep for pit mining were usually recovered using adits, inclines, or declines. When underground deposits were discovered at Ambrosia Lake, vertical shafts were sunk. Some of these shafts were wood lined. In comparison to today's maximum depths, the shafts were fairly shallow. Only small headframes (often constructed of wood) were necessary.

Though some new mines are being constructed in those areas which were productive in earlier years, the trend is for new mines to be at deeper depths. In general, these mines are also below the water table and may require a large amount of dewatering.

After development drilling has outlined the general area of the ore body, the site for the shaft (or shafts) is determined. General topography and minimizing underground ore haulage are the chief considerations in locating the shaft.

To begin a shaft the footings for the concrete collar are put in and the collar is constructed. Then the headframe is installed to allow for removal of the material from the shaft interior. To advance the shaft depth, in general, holes for blasting are drilled, the area is blasted, the loose material is hoisted, the forms for the concrete lining are put into position, and the lining increment is poured. This process is repeated until the necessary depth is reached. Power lines, and pump stations are carried downward as shaft excavation proceeds. In some cases, it may be necessary to drill dewatering wells in order to dewater the aquifers which the shaft passes through, so that shaft sinking can proceed. Grouting is used to seal off aquifers just before and during sinking through the aquifer. One company is considering freezing the area around the shaft before sinking the shaft in order to overcome dewatering problems. Other companies have first drilled the shaft and then enlarged it (For example, Church Rock 1E).

In wet mines, the shaft depth is usually to below the ore body in order to allow for haulage ways to be constructed below the mining area. Long hole drilling at points along the haulage ways is used to dewater the ore body.

In mines which are dry, the haulage ways are usually on the ore level.

A glossary of mining terms is included at the end of this chapter.

The Kerr-McGee Rio Puerco mine is currently under construction. The description of this mine's development taken from the Environmental Report is included to indicate the general development techniques used in developing a wet mine:

"The mine development phase consists of establishing sufficient access to the ore bodies to permit the production tonnage rate desired to be sustained. In the case of underground mining, this involves sinking a shaft which has been located so as to optimize the haulage distances from the various ore producing areas. Once the shaft is sunk to the ore depth, a station with ancillary drifts, pockets, trenches and sumps is developed.

The shaft at Rio Puerco will be 14 feet I.D., circular, concrete-lined, with two hoisting compartments. In each hoisting compartment, there will be a man cage with a three ton capacity skip suspended below it.

The time required to complete this size shaft to a depth of 850 feet will be 550 to 650 days. This includes completion of a pump station at 700 feet and the pocket and slusher trenches.

Before and during the shaft's construction, surface support facilities are also being constructed. The main pad area includes a main and auxiliary building, shaft area pad which includes a 90 foot high head frame, oil and fuel storage, power facilities area, perhaps a concrete batch plant (depending on economics of concrete delivery in the area), ore storage pad, and materials storage yard. The main building, as normally employed by Kerr-McGee, contains the hoist room, warehouse, maintenance shops, personnel shower and change rooms, and some engineering and administrative offices.

The area is fenced to prevent livestock entry. Inside or adjacent to the main yard area will be the topsoil stockpile, ore stockpile, water treatment facilities, and the waste rock dump. The main area to be fenced at the Rio Puerco project encompasses 72 acres.

Topsoil is removed and stacked to be used for reclamation when operations cease. The pile is seeded to prevent its erosion while stored. The ore stockpile provides surge so the mine and/or transportation system can act independently of one another.

The waste rock pile consists of barren rock produced by the shaft sinking and development headings. Attempts are made to locate this pile in an area to minimize its erosion and possible leaching by rainwater of any potential pollutants.

Total accumulation of waste rock generated by the mine project is estimated to be 370,000 tons. At the cessation of operations, some of the reserved topsoil will be placed over this pile and seeded to minimize erosion and leaching of the waste rock and to aesthetically blend it into the surrounding terrain.

The water treatment facilities are placed in a favorable gravity flow (from shaft) position with discharge access to the local drainage.

Once the shaft and surface work is completed, mine development continues with the driving of horizontal drifts outward from the shaft and beneath the elevation of the ore zone(s). These drifts are approximately 9 feet wide by 9 feet high and supported for safety purposes by rock bolts, wood sets, and/or steel sets. Haulage drifts generally parallel the long axis trend of the ore bodies. Short drifts, called crosscuts, are driven normal to the haulage drift as required to reach the extremities of the ore bodies.

These drifts are advanced by the standard drill, blast, and muck cycle. Typical development equipment includes mucking machines, jackleg drills, diesel locomotives (4 to 8 ton capacity) and 110 cubic foot rail cars which travel on 36 inch gauge track. Haulage drifts may also be excavated by mechanical mining machines such as the Alpine Miner. Haulage drifts are driven on a positive ½ to 1% grade to favor loaded trains and provide drainage toward the shaft.

As the drifts extend farther away from the shaft, the ventilation system is also developed by drilling ventilation holes. Their positions are based on the location of the ore bodies, and, of course, consistent with the overall plan of mining.

The holes are bored by a surface rig. Two methods are employed. One, the rig bores down on a pilot hole; or, two, the bit is attached at the bottom of a pilot hole and the hole reamed upward. This work is done by a Division of Kerr-McGee Nuclear or a contractor. The holes are usually 48 to 60 inches I.D. cased with a steel liner which is cement grouted. Larger holes may be employed for deeper mines.

These holes are normally used for exhaust with the fresh air intake being the production shaft. By strategic placement of these holes, the ventilation system underground is able to maintain air quality (particularly for radiation standards) as required by Federal and State mine safety regulations.

Surface acreage required for each hole is minimal. Four acres are needed as a pad area while the hole is being drilled. After completion, approximately 3½ acres are reclaimed leaving a ½ acre plot fenced around the vent hole and its fan installation.

Ore bodies are entered through raises driven from the haulage or crosscut drifts. In general, separate raises are driven for manways, ore passes, and service raises either through the conventional drill/blast cycle or with the use of raise boring machines. From the haulage drifts, rotary longholes are drilled up to delineate the ore bodies for purposes of planning the raises.

Development in the ore horizon is accomplished by driving 5' x 6' subdrifts within the ore. Initial development is followed by extensive longhole drilling laterally and vertically from the subdrift headings. Length of these longholes normally does not exceed 40 feet. If sufficient ore is located by longhole drilling programs, development drifting will resume. Advance of such headings is through conventional drilling and blasting and the muck is handled from the face to the muck raise by the use of 25 or 30 horsepower 3-drum electric slushers.

At this point, an ore body's development phase is essentially complete.

As development of ore bodies nearest the shaft are completed and they go into production, the development of more distant ore bodies continues. Thus, the transition from all development to a production status is gradual with some development continuing almost the entire span of the project. It is apparent the development drifting in the ore bodies produces some ore, and that can be said to also be the initial production. It is currently Kerr-McGee's intention to produce 510 tons/day maximum. Starting from shaft collar construction, it will take approximately four years for the mine to reach full production.

Extraction (called "stoping") of an ore body begins once development is complete. Generally, there are three stoping methods employed by Kerr-McGee: (1) open stopes; (2) room and pillar stopes; (3) square set stoping. The object of each method is to extract as much of the ore (material defined as being above a certain minimum assay) as possible. These methods normally allow recovery in excess of 90% of the ore available. Thus, maximization of a natural resource use is accomplished while simultaneously maximizing the project's profitability.

The stopes final configurations are based on several factors such as the ore body's shape, ground control in the stope, ventilation limitations, and roof control in the stope. Roof bolts, stulls, cribbing, timbering, and sandfill are variously applied as required. Sub oregrade mineralized areas may be utilized as pillars for support where they occur.

Open stoping is employed in smaller ore bodies with roof bolts and cribbing being mainly employed for roof control. Larger ore bodies of a more continuous nature will be extracted using the room and pillar method. After the development drifts (rooms) are driven, pillar robbing begins at the furthest limit and the robbing activity retreats back to the raise. Slushers used in this phase are 30 to 75 H.P., 3-drum type.

Square set stoping is employed where the ore is continuous and of greater thickness. This is done to assure both adequate roof support and high extraction rates. The sill sets are nominally 8 feet in height with the "mining floors" (upper tiers) nominally constructed 6 feet in height. Final stabilization of a square set stope may be accomplished by sandfilling once ore removal is complete.

The maximum tonnage rate will tail off as stoping is completed. At some point, ore depletion causes the project to become unprofitable at which point the decision is made to cease operations.

This results in closure procedures being put into effect. Valuable equipment and other salvagable materials are stripped from the mine. Then, a concrete plug will be poured at the collar of the shaft to seal the mine from unauthorized or accidental entry by man or animals.

The area of the ore stockpile will be thoroughly cleaned and the material sent to the mill. Trash and nonsalvagable material will be buried. The hoist headframe, buildings, and other structures will be removed. At the request of the surface owner(s), some buildings may be left intact for the owner to put to some other beneficial use.

Any foundations left from the structures removed will be destroyed. The areas disturbed will be graded and the topsoil will be redistributed. Seeding of the relaid topsoil will be done on the same basis with the same seed types as described in the section on exploration reclamation.

Roads will be scarified and reclaimed if the surface owner does not want them for his use."

Very few New Mexico mines use mechanical miners. Most mines are too small to justify the expense, and the ore bodies are so irregular that the machines can only be used for driving haulageways, etc. The sandstone also causes high maintenance costs. UNC's Church Rock mine does use Doscos. A Dosco is in use at Sec. 13 and a Dosco may be used at Gulf's Mount Taylor mine for development work there. An Alpine F6-A has been used by Kerr-McGee at their Ambrosia Lake mines and an Alpine has been used by Anaconda.

The new deeper mines are going to the use of shaft ventilation rather than ventilation via boreholes because of the reduced energy requirements with the larger shaft areas. The deep mines (3,000 feet) will also use air cooling equipment in order to keep the temperatures down to temperatures at which miners can work. (The temperature of the rock face at Mount Taylor will be about 130°F).

Some of the operators, at mines which are being sunk very deep, have indicated that they feel that the shaft dewatering wells have aided more than grouting in controlling water infiltration. Selection of the proper grout is very critical. Depending on the success of shaft freezing, future deep mines may incorporate dewatering wells as normal operations in shaft sinking.

Several mines in New Mexico have received or are receiving sand back fill. The status of sand backfill in New Mexico is given in Table VI-1. As was mentioned in the Rio Puerco discussion, sand backfill is usually used for structural support. The sand may be wind blown sand or sand recovered from milling operations.

Currently, Kerr-McGee is recovering sands off the cyclones in the sand-slimes separation circuit of the mill. These sands are used at Kerr-McGee's Section 35 and 36 mines and at Rancher's Johnny M Mine. Presently, about 1,000 tons a day are being used at 35 and 36. This sand is stored in the mill area and is transported to the mines by truck. In the mined out area of the mine, a bulkhead is constructed. The sand is mixed with water (50-50 Ranchers and 70-30 at Kerr-McGee) and is slurried from the surface to the top of the bulkhead. The sand is then deposited in the open area behind the bulkhead. The water drains from the sands into sumps where it is pumped to the surface. Once the sands are drained further stoping in front of the bulkhead can begin. Over 100 tons an hour of sand can be emplaced in each of the current operations.

This sand backfill technique if successfully used allows for almost complete ore recovery in thick beds without mine collapse causing inter-aquifer connections.

In December of 1977 sand backfilling was not successfully used to prevent collapse, and in Section 35 a connection was made from the Westwater, in which the mining was being conducted, and the Dakota which is above the Westwater. Mine dewatering rates increased by a factor of approximately two until the area was sealed off.

Another mining technique in use today in "worked out areas" is mine water recirculation. In the early years of mining cutoff grade was usually about .15% U_3O_8. As retreat began in these mines, the roof collapsed. When this happens further ore recovery using traditional techniques is difficult. To further increase recovery, many mine owners have drilled holes to the top of the collapsed zone and are spraying water through these holes onto the low grade shattered ore. Mine water is slightly alkaline and a small amount of leaching occurs as the water runs through the shattered zone into collection sumps. The enriched water is then pumped to central ion exchange facilities where the uranium is removed from the water. The water, allowing for discharge of any excess, can then be returned for further leaching. After a period of time no further leaching may occur. Then the shattered zone is allowed to "sit" until further oxidation of the ore via natural processes occurs (usually about two weeks).

TABLE VI-1

SAND BACKFILLING IN NEW MEXICO MINES

Company	Mine or Proposed Mine	Has Had BackFill	Will Have BackFill
UN-HP	Ambrosia Lake Mines	yes	N/A
Ray Williams	Enos Johnson	yes	no
Mobil	Crownpoint*	-	yes
Kerr-McGee	Section 17	no	if necessary
Kerr-McGee	Section 19	no	if necessary
Kerr-McGee	Section 22	yes	yes
Kerr-McGee	Section 24	no	if necessary
Kerr-McGee	Section 30	yes	yes
Kerr-McGee	Section 30 W	no	if necessary
Kerr-McGee	Section 33	no	if necessary
Kerr-McGee	Section 35	yes	yes
Kerr-McGee	Section 36	yes	yes
Kerr-McGee	Church Rock #1	no	if necessary
Ranchers	Johnny M	yes	yes
Gulf	Mount Taylor*	-	yes
Kerr-McGee	Rio Puerco*	-	if necessary
Cobb	Section 12	yes	yes
Conoco	Bernabe*	N/A	N/A
Conoco	Crownpoint*	N/A	N/A
UNC	Dalton Pass*, Sec. 30* Sec. 34*	-	waste rock if necessary
UNC	Church Rock	N/A	undergoing study
UNC	Sandstone	N/A	N/A
UNC	Ann Lee	N/A	N/A

TABLE VI-1 (cont)

Company	Mine or Proposed Mine	Has Had BackFill	Will Have BackFill
UNC	Section 27 E	N/A	N/A
Gulf	Mariano Lake	no	may have waste
Ranchers	Hope	N/A	N/A
Phillips	Nose Rock*	-	yes
UNC	St. Anthony*	N/A	N/A
Kerr-McGee	Church Rock #2*	-	if necessary
Calumet & Helcla, Inc.	Marquez (inactive)	yes (blow sand)	

*under construction or planned

Mines undergoing mine water recirculation are shown in Table VI-2.

Mine dewatering water is also run through the ion exchange plant in many cases in order to recover the uranium. While the amount of uranium produced from mine waters was rather small in 1977 (less than 100 tons U_3O_8) this extraction process is cheap and hence represents a small profitable operation for the mine owners.

Another type of uranium recovery technique is to use an in-situ method. In a project currently being tested in New Mexico by Mobil near Crownpoint injection wells are drilled in a five spot pattern 100 feet apart. Weak alkaline solutions containing an oxidant will be injected in the four outer wells and the leached solution will be recovered in the center well. The pregnant leachate will next be passed through an ion exchange column containing resin. The uranium will then be removed from the resin in another column, precipitated, and dried. In order to contain the leachate and to have a successful operation (1) the ore zone must be saturated, (2) there must be a net production of water, (3) the ore body must be uniformly permeable, and (4) it is helpful to have impermeable material overlying and underlying the ore bearing unit. Figure VI-1 illustrates the major aspects of this type of extraction technique. The present New Mexico project is designed to recover uranium from nearly 2000 feet and if successful, will be a first for this depth.

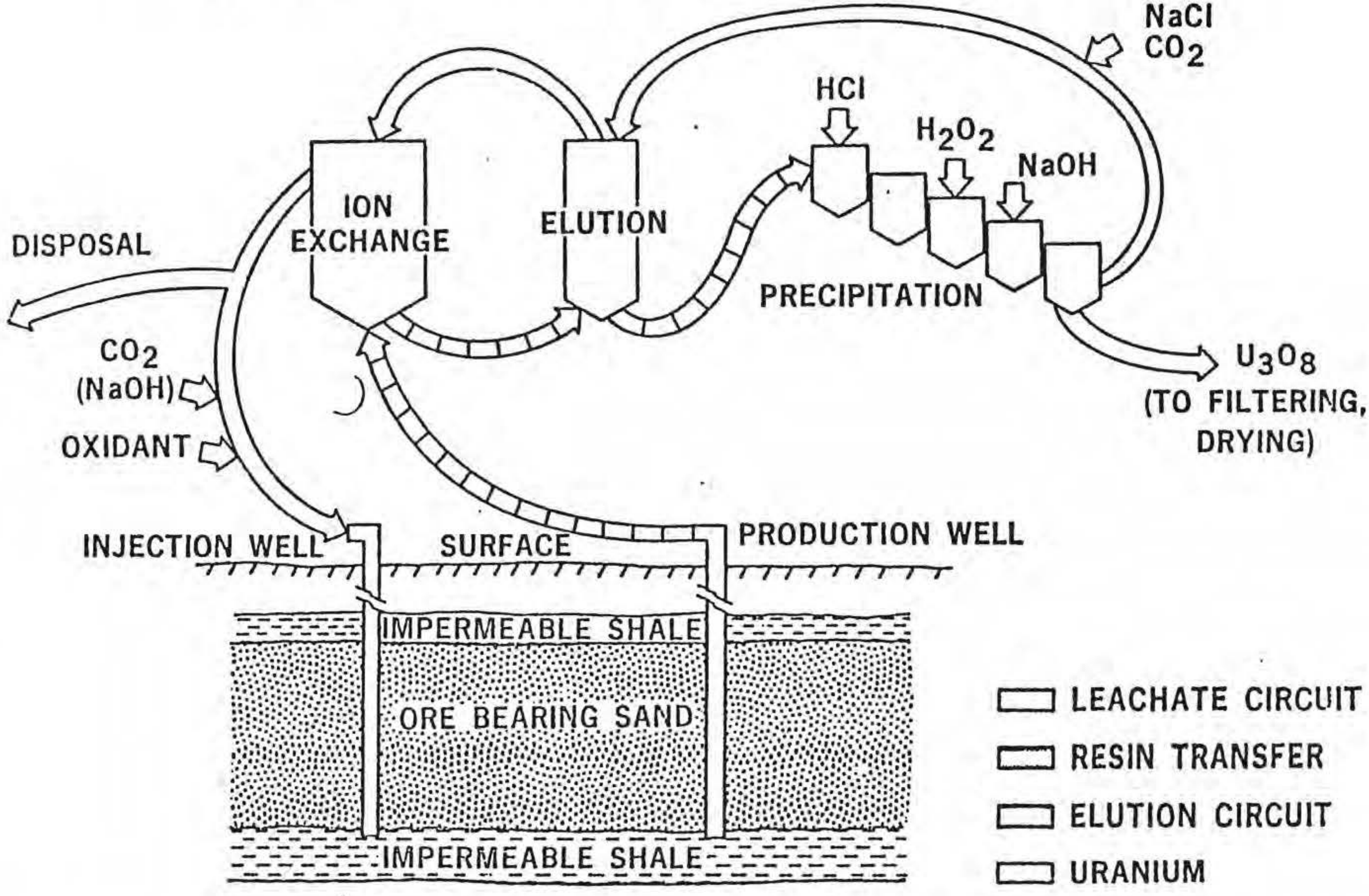
TABLE VI-2

MINE WATER RECIRCULATION

Company	Mine	Is Undergoing Recirculation	Will Undergo Recirculation
UNC	Ann Lee	yes	
UNC	Section 27 E	yes	
UNC	Sandstone	yes	
Kerr-McGee	Section 17	yes	
Kerr-McGee	Section 22	yes	
Kerr-McGee	Section 24	yes	
Kerr-McGee	Section 30	yes	
Kerr-McGee	Section 30 W	yes	
Kerr-McGee	Section 33	yes	
Kerr-McGee	Section 19		yes
Kerr-McGee	Section 35	to slurry sands	
Kerr-McGee	Section 36	to slurry sands	
UN-HP	Section 23	yes	
UN-HP	Section 25	yes	
Ranchers	Johnny M	to slurry sands	

FIGURE VI-I

IN-SITU URANIUM LEACHING PROCESS



Source: Mobil

Companies having IX plants to recover uranium from mine water dewatering, mine water recirculation, and in-situ leach projects are listed in Table VI-3.

Heap leaching is also a uranium recovery method which has been employed in New Mexico. In this type of operation the ore is piled in heaps above drain tiles. A suitable solution is applied to the heaps. The solution runs through the ore and is collected in the drains. The uranium is then extracted from the pregnant liquor and the solution recycled.

Kerr-McGee use to have a small heap leach operation near their tailings pond and UNC has an abandoned operation in front of the San Mateo mine. UNC plans to operate a pilot plant leach operation for low grade ore (about .01%-.03% U_3O_8) on their Ambrosia Lake property. The pregnant liquor will go to their present IX plant. Union Carbide is studying the feasibility of heap leach if they develop their Diamond Tail property.

Inactive Mines in New Mexico

It is not known how many inactive mines are located in New Mexico. Lowell Hilpert states in the Geological Survey Professional Paper 603 that production in northwestern New Mexico from 1950-1964 came from 175 mines. It would be assumed that some mines developed after 1964 may be inactive while several mines developed before 1964 continue to be active or have been reopened.

Table VI-4 is a list of some of the mines no longer in operation. This data was obtained from the State Mine Inspector. Only a few of the mines have been field checked as to location by the Energy and Minerals Staff. The field survey program at the present time has failed to locate two mines in their stated locations and located one mine not listed in the table. Several of the larger mines which have been located in the present field survey will be described below.

Church Rock Area

The Church Rock Mine is located in T 16N R16W Section 17. It was mined in both the Dakota and Westwater from a vertical shaft during 1960-1962 by the Phillips Petroleum Company. United Nuclear plans to

TABLE VI-3

URANIUM IX PLANTS IN NEW MEXICO

Company	Location
UNC	Church Rock (Mine)
UNC	Ambrosia Lake (Mines)
UN-HP	Ambrosia Lake (Mines)
Kerr-McGee	Ambrosia Lake (Sec. 35)
Kerr-McGee	Ambrosia Lake (Western section of mines)
UN-HP	Milan (mill-tailings pond recirculation)
Mobil*	Crownpoint (In-situ project)
Gulf±	Mariano Lake (Mine)
Gulf**	Mt. Taylor (Mine)
UNC***	Old Church Rock (Mine)

*Mobil has not yet begun uranium recovery but the skid mounted unit is on the property. (November, 1978)

±Will start-up in Spring 1979

**Will be operated when mine production begins, probably late 1979

***Will be installed soon

TABLE VI-4

Inactive New Mexico Uranium Mines
Location Grants to Ambrosia Lake

Mine	Company	Township & Range	Area
Barbara #3	Bailey & Fife	T13N R9W Sec. 30	Poison Canyon
Beacon Hill Incline	Farris	T13N R9W Sec. 20	Poison Canyon
Blue Peak	Garcia	T13N R10W Sec. 24	Poison Canyon
Buckey #1	(See-Tee)	T14N R10W Sec. 14	Near Kerr-McGee mill~2½ miles
Sec 4 Dakota Mine	Farris	T13N R10W Sec. 4	NE of Haystack Mt. (Goat Mt. Quad.)
Dalco #1	Dalco	T13N R9W Sec. 30	Poison Canyon
Davenport	Black Rock	T13N R9W Sec. 20	Poison Canyon
Dog Mine	Four Corners Ex.	T13N R9W Sec. 20	Poison Canyon
Flea Mine	Four Corners Ex.	T13N R9W Sec. 20	Poison Canyon
Mesa Top	(See-Tee)	T13N R9W Sec. 20	Poison Canyon
Doris Incline	Bailey & Fife	T13N R9W Sec. 21	NE of Poison Canyon
Doris #2	KSN (Phillips)	T13N R9W Sec. 21	NE of Poison Canyon
Westvaco	SFRR	T13N R9W Sec. 29	Poison Canyon
Dysart #1	UNC	T14N R10W Sec. 11	~3½ miles N of Kerr-McGee Mill
Dysart #2 (SE Shaft)	UNC	T14N R10W Sec. 11	~3½ miles N of Kerr-McGee Mill
Dysart #3 Mary #1	Homestake-Sapin	T14N R10W Sec. 11	~4 miles N of Kerr-McGee Mill
Stella Dysart #12	(See-Tee Mining)	T14N R10W Sec. 20	N of Haystack (Goat Mt. Quad)
Faith	KSN	T13N R9W Sec. 29	Poison Canyon
Farris	Farris	T13N R9W Sec. 33	E of Poison Canyon
Flat Top	Bailey & Fife	T13N R9W Sec. 30	Poison Canyon

TABLE VI-4 (continued)
Grants to Ambrosia Lake

Francis Mine	Farris	T14N R11W Sec. 8	North of Haystack (Goat Mt.)
Glenn & Edith	Federal Uranium	T13N R11W Sec. 24	South of Haystack
Gossett	Farris	T13N R9W Sec. 18	Poison Canyon
H-H-50 Roundy	Bailey & Fife	T13N R9W Sec. 30	Poison Canyon
Homer Scriven	Mesa	T13N R10W Sec. 36	SW of Poison Canyon
Hanosh	Hanosh	T12N R10W Sec. 26	
Haystack #2	B & H Trucking	T13N R11W Sec. 13	Haystack
Hogan	Four Corners	T13N R9W Sec. 14	Off San Mateo Road past Ambrosia Lake "Y"
Ike #1	Rio De Oro	T14N R9W Sec. 26	West of Kerr-McGee
Isabella	KSN	T13N R9W Sec. 6 & 7	South of Kerr-McGee Mill
Kermac Sec. 10	Kermac	T14N R10W Sec. 10	West of drylake called Ambrosia Lake
Marquez	Kerr-McGee	T13N R9W Sec. 23	Off San Mateo Road to South past "Y"
No. 4 Moe	Sutton	T13N R9W Sec. 32	East of Posion Canyon
Chill Wills	Farris	T13N R9W Sec. 24	Off San Mateo Road to South past "Y"
Rimrock	Sutton	T13N R10W Sec. 36	SW of Poison Canyon
Rimrock (pit) Q-32 T-9	Bailey & Fife	T13N R9W Sec. 30	Poison Canyon
Federal Mine Sec. 18	Mesa (Cibola)	T13N R10W Sec. 18	Haystack Mt.
Section 19 (pit)	UNC	T13N R10W Sec. 19	South of Haystack
Haystack Sec. 23	Dole	T13N R10W Sec. 23	Between Haystack Poison Canyon
Sec. 25 Haystack	Farris	T13N R10W Sec. 25	Between Haystack Poison Canyon

TABLE VI-4 (continued)
Grants to Ambrosia Lake

Sec. 31 Haystack	SF Pacific RR UNC	T13N R9W Sec. 31	South of Poison Canyon
Silver Spur	Farris	T14N R10W Sec. 31	North of Haystack (Goat Mt.)
Vallejo	Penta	T13N R9W Sec. 34	East of Poison Canyon
Black Hawk & Bunny	Bailey & Fife	T12N R9W Sec. 4	SE of Poison Canyon
Bonanza #1	Trust Co.	T12N R9W Sec. 11	La Jara Mesa
F-33	Homestake	T12N R9W Sec. 33 & 34	East Grants Ridge
Falcon #1	Falcon	T11N R9W Sec. 20	NE of Grants ~22 Miles
Zia La Jara	Anaconda?	T12N R9W Sec. 15	North of Grants near La Jara Mesa
Section 9 (strip)	Anaconda	T12N R9W Sec. 4 & 9	Near La Jara Mesa
Red Bluff 8 & 10	Cheyenne	T12N R9W Sec. 4	
San Mateo	UNC	T13N R8W Sec. 30	About 4 miles west of San Mateo

Location: Laguna-Marquez

Mine	Company	Township & Range	Area
Alpine Miner	Anaconda	T10N R5W Sec. 2	South of Paguate
Jackpile underground H-1	Anaconda	T10N R5W Sec. 3	near Paguate
M-6	St Anthony	T11N R4W Sec. 30	North of Jackpile
South Laguna	Anaconda	T9N R5W Sec. 22, 27 T8N R5W Sec. 7, 8	South of Jackpile
Woodrow Mine	Anaconda	T10N R5W Sec. 1 T11N R5W Sec. 36	East of Paguate

Location: Smith Lake

Alta Group	Fay & Company (Farris)	T14N R11W Sec. 5 & 6	8MN Prewitt
Black Jack #1	UNC	T15N R13W Sec. 12	West of Smith Lake
Black Jack #2	UNC	T15N R13W Sec. 18	West of Smith Lake
Mac #1	UN-HP	T15N R14W Sec. 12	South of Mariano Lake
Mac #2	UN-HP	T15N R13W Sec. 18	West of Smith Lake
Silver Bit	United Western	T14N R12W Sec. 10	Near San Antonio

Location: Church Rock-Gallup

Becenti	WCT Engineering	T15N R17W Sec. 28	South of Rehoboth
Church Rock	UNC	T16N R16W Sec. 17	Near Springstead
Foutz #2	Four Corners Uranium	T15N R16W Sec. 5	North of Wingate
Hogback #4	Windsor	T15N R18W Sec. 12	North of Gallup
Largo #2	Largo Uranium	T15N R17W Sec. 33	South of Rehoboth
Diamond #2	Jamieson	T15N R17W Sec. 28 & 33	

Location: Church Rock-Gallup (cont)

Mine	Company	Township & Range	Area
Rimrock #1	MP Grace	T15N R16W Sec. 3	North of Wingate area
Rimrock #2 Williams & Mary	MP Grace	T15N R16W Sec. 4	North of Wingate area

Location: Other

Junio	Robert B. Daniel	T9N R1W	15 miles North Albuquerque
Datil	Farris (Ranchers)	T2N R10W Sec. 19	
Quary	Mandeville Mining	T8S R17W Sec. 27	
Begay #2	Fritz-Erickson	T29N R21W Sec. 24	
King Tutt	Sylvania	T29N R21W Sec. 24	
Nelson Point	Foote Mineral	T29N R21W	

reopen this mine in the near future. UNC has reported that the old low grade ore surrounding the mine was sent to the mill for recovery.

Smith Lake Area

Black Jack #1 (T15N R13W Section 12) was mined by UNC via an 825' foot shaft during 1959-1964. The ore was located in the upper half of the Westwater. Old buildings and foundations remain at the site. Old ore storage areas and mine waste dumps give gamma readings in excess of background. The shaft has been covered with a cement cover.

Black Jack #2 (T15N R13W Section 18) was operated by UNC and began production in 1960. The ore is located in the Brushy Basin member of the Morrison Formation. One building is presently standing. The main ventilation shaft is open and this area has collapsed. Another ventilation hole near the building is open. The shaft has a concrete slab across it. Gamma levels in excess of background occur around the mine area. Transport of waste piles and old ore storage areas by rain runoff is apparent. This mine may be reopened as a joint venture by Cobb Nuclear and Anschutz.

Mac #1 (T15N R14W Section 12) was operated by UN-HP. Two buildings remain at the site. The shaft has been covered by a concrete slab. Waste piles give gamma readings in excess of background. The mine waste is moving both via water and air transport.

Mac #2 (T15N R13W Section 18) was also operated by UN-HP. This was apparently a rather small facility. The shaft has been covered with a concrete slab. Waste piles surrounding the shaft have external gamma levels above natural background.

Poison Canyon Area

The F-33 mine is located in T12N R9W Section 33 and Section 34 at the base of the East Grants Ridge. The mine was worked via two declines. Anaconda was operating the mine when it was closed in 1976. The ore was removed from the Todilto Limestone. There are waste benches at the entries. Two of the entries are open except for wire mesh. The waste benches have higher gamma levels than surrounding natural soils. The south bench gives higher levels than the north bench.

Along the Todilto Limestone bench north of F-33 and on the east of the San Mateo drainage there are a series of pit, extended pit, and adit mines. These include Zia (T12N R9W Section 15) and in T12N R9W Section 4 and 9 Christmas Day #1, Black Hawk/Bunny, Red Bluff, Gray Eagle, UDC Section 4, Vallejo, Anaconda Section 9, and Last Chance. These mines operated during the 1950's and early 1960's. No land restoration has been undertaken and the limestone bench in this area is covered with pits and/or waste materials. Waste is beginning to wash into the valley below. Gamma levels of the mine waste while not as high as many mine wastes in New Mexico, are above background.

Another long bench of Todilto Limestone runs west-east in the Poison Canyon area. This area also contains pits, extended pits, and adits. Little restoration has been done in this land area which includes T13N R9W Section 31 and Section 30, and T13N R10W Section 25, Section 26, Section 23, Section 16, Section 18, Section 19, and T13N R11W Section 24 and Section 13. The mines include Haystack 31, Rimrock, Haystack 25, Section 19, Hanosh, Haystack 23, Red Point #1, Haystack 1 and 2, Glenn and Edith, Federal, and Section 19. These mines were active in the 1950's and early 1960's. Waste material has gamma levels above background. Ore recovery was from the Todilto Limestone.

Moving inward from the Todilto Limestone bench are several shaft mines. Flat Top is located in T13N R9W Section 30 and was operated during the 1960's. The shaft entry has logs across and a small concrete slab. An unlocked door gives access to the mine via a ladder. Waste piles having gamma levels above background are around the shaft area.

A mine whose name is not known is located in T13N R10W Section 24. The headframe is still standing and the shaft has a ladder down it. Open vent holes and gamma levels above background were noted in the area.

The Westvaco (Faith) apparently extended down to 450 feet in T13N R9W Section 29. The entry has caved into a large hole in the ground. Ore material giving gamma levels approximately 50 times background was falling into the nearby arroyo.

The Roundy, (T13N R9W Section 30), Barbara J. #1 (T13N R9W Section 30), the Barbara J. #2 (T13N R9W Section 30), and the Barbara J. #3 (T13N R9W Section 30) were mined in the 1950's and 1960's. Open vents and mine wastes were also noted in the areas of these mines. The new Todilto mine will connect to the Roundy mine and Barbara J. #2 mine.

San Mateo

The Marquez mine (T13N R9W Section 23) was operated in 1958-1965 by United Nuclear. The entry, a decline, is presently closed with wire mesh. An extensive waste bench extends out from the entry. Gamma activity levels on the bench are up to 50 times background. The road to the mine also has gamma levels in excess of background. Ore recovery was from the Brushy Basin and mining problems were encountered.

The San Mateo mine (T13N R8W Section 30) was operated by UNC. Mining problems were experienced due to the swelling of clays in the Brushy Basin member of the Morrison. The ore was removed via a shaft which is presently covered. Building foundations and general debris such as water heaters, ducts, etc., remain at the site. A bench of about 10 acres extends outward from the mine area. This bench is about 100 feet at its face above the valley floor. The bench material is beginning to move towards the valley floor. Gamma activities on the bench are in excess of background. In front of the mine towards San Mateo Creek is a heap leach pad consisting of two cells covering an area of .34 acres. Again gamma levels are in excess of background. This mine may be reopened by UNC.

Chill Wills (T13N R9W Section 24) was operated in the 1960's. Piles of waste surround the mine.

Hogan (T13N R9W Section 14) was operated between 1959-1962. The shaft is covered with a concrete slab, but there are two holes in the very weathered slab. Piles of random waste are around the site.

Ambrosia Lake

Spencer Shaft (T13N R9W Section 8) is a wood cribbed shaft. It is being reopened by Koppen. Koppen also hopes to reopen at least part of the Isabella (T13N R9W Section 6 and 7).

The Rio Del Oro (Dysart #1) is located in T14N R10W Section 11. It was an early underground mine about 300 feet deep. Approximately 900,000 tons of .21% grade ore was removed (max. 1500 T/day) from the Westwater during 1956-1962. The headframe and hoist building are still standing.

The Mary #1 (T14N R10W Section 11) as of April 1978 still had its headframe standing. However, it was reported to be dangerous to go near as the whole area was in danger of collapse. Mary was operated by Homestake in 1959-1965.

The Dysart #2 (T14N R10W Section 11) was active from 1959-1963. At the present time Cobb is using the shaft as a vent hole for their Section 12 mine. The low grade ore piles surrounding the site give gamma levels approximately 50 times background.

Buckey (T14N R10W Section 14) was operated by See-Tee in 1957-1965. The shaft is wood cribbed. The headrame is in place; however, the shaft, though surrounded by a fence, is open. An open vent hole is nearby. Readings taken of gamma levels gave levels greatly in access of background for a large area around the mine.

Santa Fe County

The La Bajada mine (T15N R7E Section 9) had uranium removed from a pit near the diverted Santa Fe river in the 1960's. Though the pit is now flooded, Lone Star Mining has indicated that it might be interested in reopening the mine. Piles of waste having levels of radioactivity of up to 40 times natural background are located along the river on both sides of the pit. These waste piles have very little vegetation on them, and surface water run off is carrying the material in these piles towards the river.

Active Mines

There are presently 32 mines in active ore production in New Mexico. Two mines are undergoing mine water recirculation only. Data on these mines is given in Table VI-5

The active mining regions can be divided up into several general areas. Beginning from West to East there is first the Springstead (Church Rock) area. This region is about 10 miles north of Church Rock or about 15 miles northeast of Gallup. In this area are located the Church Rock mines of UNC and Kerr-McGee and the old Church Rock mine. Moving east is the Smith Lake region. Smith Lake is approximately 14 miles northeast of Thoreau. In this region are Mariano Lake, Ruby #1, and Westranch. North from Smith Lake about 10 miles is Crownpoint. In this general area is the Dalton Pass, the Borrego Pass, Nose Rock, the

ACTIVE NEW MEXICO MINES - 1978 - TABLE VI -5

NAME	COMPANY	LOCATION	TYPE	EMPLOYMENT	MAXIMUM DEPTH FEET	NO. EXHAUST VENTS	MINE PRESSURE	AIR DISCHARGE ACFM	GPM MINE WATER PUMPED OUT	MINING TECHNIQUE
Section 22	Kerr-McGee	T14N R10W Section 22	vertical shaft (v.s.)	-	827	-	-	-		mine water recirculation only
Section 33	Kerr-McGee	T14N R9W Section 33	vertical shaft	-	848	-				mine water recirculation only
Section 30	Kerr-McGee	T14N R9W Section 30	v.s.	185	750	11	neg.	348,500		MR & P
Section 24	Kerr-McGee	T14N R10W Section 24	v.s. 9' x 16'	66	837	8	neg.	170,000	2500	MR & P
Section 17	Kerr-McGee	T14N R9W Section 17	v.s.	95	1,094	11	neg.	250,000		
Section 30W	Kerr-McGee	T14N R9W Section 30	v.s. 152" ID	184	810	4	neg.	265,000		MR & P
Section 19	Kerr-McGee	T14N R9W Sec. 19		150	779	6	neg.	205,000		
Section 35	Kerr-McGee	T14N R9W Sec. 35	v.s. 14' dia	210	1,398	6	neg.	414,000	1600	
Section 36	Kerr-McGee	T14N R9W Sec. 36	v.s. 14' dia	147	1,473	4	push-pull	190,900	1600	
Church Rock #1	Kerr-McGee	T17N R16W Sec. 35	v.s. 14' dia.	319	1,851	4	neg.	392,000	3200-4000	R & P
Ann Lee	UNC	T14N R9W Sec. 28	v.s.	9	720	2	neg.	80,000	350-400	MR & P
Section 27	UNC	T14N R9W Sec. 27	v.s. two shafts 60" ID	39	850	3	neg.	166,000		
Sandstone (John Billy Shaft)	UNC	T14N R9W Sec. 34	v.s. 12' dia John Billy 60" ID	120	940	3	neg.	230,000	350	

ACTIVE NEW MEXICO MINES - 1978 - TABLE VI-5
(Cont.)

NAME	COMPANY	LOCATION	TYPE	EMPLOYMENT	MAXIMUM DEPTH FEET	NO. EXHAUST VENTS	MINE PRESSURE	AIR DISCHARGE ACFM	GPM MINE WATER PUMPED OUT	MINING TECHNIQUE
Church Rock	UNC	T17N R16W Sec. 35	v.s. two shafts 14' dia 12' dia	540	1800	5	neg.	667,500	~1300-1400	
St. Anthony	UNC	T11N R4W Sec. 19 & 30	pit-one active one inactive		~150-200	-	-	-	20-50	pit
Section 25	UN-HP	T14N R10W Sec. 25	v.s. 132" x 168"	100	811	7	neg.	291,500		MR & P
Section 23	UN-HP	T14N R10W Sec. 23	v.s. 14 feet	163	850	12	neg.	500,000	1800-2000	MR & P
Section 32	UN-HP	T14N R9W Sec. 32	v.s. 47' x 11.4'	22	595	3	neg.	81,000		MR & P
Section 15	UN-HP	T14N R10W Sec. 15	shaft - (inoperative) decline	21	623	4	positive	251,580	dry at moment	MR & P
Section 13	UN-HP	T14N R10W Sec. 13	v.s. 12' 8" dia.	40	618	1	neg.	145,000	dry	
Johnny M	Ranchers Exploration	T13N R8W Sec. 7 & 18	v.s. 14' dia.	180	1380	2	neg.	140,000	1000	backfill
Hope	Ranchers Exploration	T13N R10W Sec. 19	v.s. 8' dia.	33	400	1	neg.	48,000	almost dry	trackless MR & P
Poison Canyon (connects to Gosset)	Reserve Oil & Min.	T13N R9W Sec. 19	adit 3500' long 9' x 9'	29	200 below cliff	5	neg.	63,945	dry	MR & P
Section 12 (connects to Dysart #2)	Cobb	T14N R10W Sec. 12	v.s. 14' ID	33	665	1	neg.	64,000	dry	
Westranch (portal Sec. 33)	Cobb	T15N R11W Sec. 32	Shaft-inactive decline 800' long 20°grade	14	-	1	neg.	8,000	dry	MR & P

ACTIVE NEW MEXICO MINES - 1978 - TABLE VI-5 (Cont.)

NAME	COMPANY	LOCATION	TYPE	EMPLOYMENT	MAXIMUM DEPTH FEET	NO. EXHAUST VENTS	MINE PRESSURE	AIR DISCHARGE ACFM	GPM MINE WATER PUMPED OUT	MINING TECHNIQUE
Ruby #1	Western Nuclear	T15N R13W Sec. 21	decline 9' x 14' 2,134' 11% grade	54	388	3	neg.	361,000	dry	MR & P
Mariano Lake	Gulf	T15N R14W Sec. 12	v.s. 5' x 16'	150	519	1	neg.	83,000	200-300	MR & P
JJ #1	Sohio	T11N R5W Sec. 13	v.s. 14'	120	672	3	neg.	200,000	25	trackless and sublind stoping
Pw-2/3	Anaconda	T11N R5W Sec 33	adits							
P-10	Anaconda	T10N R5W Sec. 4	decline 9' x 16' 13% grade	188	450	7	push-pull	335,000	~ 150	MR & P
Jackpile-Paguate	Anaconda	T11N R4W Sec. 33, 34, 35 T10N R4W Sec. 2,4, & 5	pit	~ 435	pits - 150				dry	pits - over 2000 acres now disturbed
Haystack	Todilto Exp. & Develop. Corp.	T13N R10W Sec. 19	pits and adits	14	150	1	neg.	16,000	dry	pits and MR & P
Spencer Shaft	Koppen	T13N R9W Sec. 8	v.s.	12	300			N.A.	dry	
Enos Johnson	Ray Williams	9 N W Sanostee Boarding School	adit 4000' in	4	-	1		28,000	dry	
Sec. 21 (Doris Extention connects to Flea)	M & M	T13N R9W Sec. 21	adit 8' x 9' decline 900' m	9	-	1		52,500	dry	

V.S. - Vertical Shaft

MR & P - Modified roomand pillar

Narrow Canyon and the several Crownpoint projects either under development or expected. Moving east again is the Poison Canyon area about eight miles north of Milan. In this region the Hope, Poison Canyon, Haystack, and Section 21 mines are located. Northward from the Poison Canyon area about 10 miles lies the Ambrosia Lake region. This region contains Sections 22, 33, 30, 24, 17, 30W, 19, 35, and 36 of Kerr-McGee, Sections 25, 23, 15, 32, and 13 of UN-HP, Ann Lee, Section 27, and Sandstone of UNC, Section 12, and the Spencer shaft. To the west of Ambrosia Lake a short distance is the San Mateo region. Here the Johnny M and Mount Taylor projects are found. Moving westward is the Laguna, Paguate, Seboyeta region. In this region the Jackpile - Paguate, P-10, JJ #1, and St. Anthony mines are located, Northwest of Seboyeta about 19 miles by road is Marquez. The Bokum Resources' mine is being developed here. Westward from Seboyeta is the region located along the edge of the Rio Grande Rift. The western most mine in this area is the Rio Puerco with the Bernabe project located to the Southeast. Figure II-1 indicates these general areas.

Random facts have been gathered from non-confidential data sources for some of the active New Mexico mines. These are discussed for the appropriate mines in the following section.

Sohio's JJ #1 mine has an expected lifetime of 10-15 years. About 15 million pounds of U_3O_8 will be recovered from the Jackpile Sandstone in the property. The ore grade runs between .1 - .4% U_3O_8 and will probably average .18%. The ore is sent to the Sohio mill directly down the hill from the mine. A second underground mine or pit may be developed later. When full production is reached it is hoped that JJ #1 will produce about 1,000 T/day. Mine waste is expected to be 400,000 tons of barren soil and rock and 100,000 - 200,000 tons of low grade (U_3O_8 containing) material. Trouble has been experienced in the mining operation due to swelling of the clays in the Brushy Basin.

Kerr-McGee's Church Rock I mine has a production goal of over 1000 T/day. The mine waste bench is presently more than 30 acres. Any mined rock less than .03 - .05% U_3O_8 is placed on the waste bench. The heat output of the mine is about 350,000 Btu/min. An additional production hoist facility is being constructed at Church Rock. Initial development costs were $15 million.

UNC's Church Rock mine produces through two shafts in order to achieve a production capacity of up to 3000 tons/day. This property contains about 20 million tons of ore having an average grade of .15% U_3O_8 (60 million pounds U_3O_8).

Reserves in UNC's Ambrosia Lake properties were reportedly 3.66 million tons of ore with an average U_3O_8 content of .1% (7.4 million pounds U_3O_8) in 1977. In 1977, production on all UNC New Mexico properties was 2.8 million pounds U_3O_8.

Rancher's Johnny M mine has been receiving sand backfill from Kerr-McGee's mill. Production during the final quarter of 1977 was 240,000 lbs. of U_3O_8 compared with an output of 191,000 lbs for the previous quarter.

Gulf's Mariano Lake mine began production in 1977. Ore reserves before mining began were approximately 3.5 million pounds of U_3O_8. By the time the mine achieves full production it is hoped that 625 tons a day of ore can be produced. Average ore grade is about .24%, cut-off is at present about .1%. The ore is not always in secular equilibrium with its daughters and this causes some problems in determining ore grade. By 1981-1982 it is projected that the ore body will be exhausted after having produced 750,000 tons or more of ore. Mining problems have been encountered due to the need to meet early delivery commitments. The ore has had to be mined wet before it was properly dewatered. Retreat is inward-outward. Any ore which runs .05 - .1% U_3O_8 is stockpiled and is not at present being taken to the mill.

Western's Ruby #1 mine is presently producing about 500 tons a day of ore with an average grade of .17% U_3O_8. Cut-off is .05% but any ore which is removed and runs .03% or above is stockpiled. The ore body is in the Brushy Basin and in contrast to Mariano Lake the ore is in secular equilibrium. It is anticipated that this mine will close in 1980.

Anaconda's Jackpile-Paguate consists of two separate ore bodies. The Jackpile complex is approximately 1.5 miles long and over 5 miles wide while the Paguate is 2 miles long and several hundred feet wide. The elements Se, V, and Mo are associated with the deposits. During 23 years of mining 660 acres of open pit area have been produced and overburden has been deposited over 1080 acres. Before mining is finished in 1983 Anaconda will expand the open pit surface area by 90%. Total disturbed area 1976 - 1981 is estimated to be 2650 acres. In

1976 the ore was blended to .23% U_3O_8 for sending on unit trains to the Bluewater mill. In 1977 it was projected that 499,000 tons of ore containing .04% or more of U_3O_8 with an average grade of .19% (1,925,000 lbs U_3O_8) would be mined from the pits. The tons of associated material mined with the ore was projected to be 1,740,000 tons. In 1978 projections are for 768,000 tons of ore containing an average grade of .14% (2,213,000 lbs U_3O_8) with 2,651,000 tons of associated material. Total tons stripped in 1977 were estimated at 26,000,000 and in 1978 at 21,421,000. Mining is projected to cease in 1982 after the ore grade falls to .15% U_3O_8. During these years stockpile reclaim will also be carried on. Stockpile reclaim should cease in 1985. It was estimated that 1,058,000 pounds of U_3O_8 would be reclaimed from stockpiles in 1977 and 1,557,000 lbs of U_3O_8 in 1978. The ore plus low grade to stripping and waste ratio averaged 1:6.13 from 1965-1975.

The P-10 decline of Anaconda's produces about 1000 tons a day of ore. The ore is crushed and conveyed to the surface on a conveyor belt. P-10 is projected to close in 1980. Average grade of ore varies and is projected to drop from .34% in 1977 to .15% in 1980.

Mines Under Development

At present there are eight mines under development (Table VI-6), including old mines being reopened. There is one in-situ pilot plant facility undergoing development and start-up.

Random facts on the mines now under construction are discussed below.

Kerr-McGee's Church Rock IE project is enlarging the east vent hole into a diameter large enough to permit it to be used for hoisting. The advantage of this technique is that muck is removed from the bottom of the hole and lifted from the main shaft. This process is proving to be a fast way for shaft development. The modification will allow for increased production at Church Rock I to about 1500 T/day and will decrease the underground ore haulage distance for ore mined from the east ore body. A similar shaft will probably be built at Church Rock I W.

Kerr-McGee's Rio Puerco mine contains uranium reserves of approximately 3.2 million pounds of U_3O_8. In the main Rio Puerco deposit in the Westwater member several zones of mineralization more or less coalesce over an area approximately 6,000 feet long and 1,000 feet

TABLE VI-6

N.M. URANUIM RECOVERY PROJECTS UNDER DEVELOPMENT (NOVEMBER 1978)

NAME	COMPANY	LOCATION	EXPECTED DEPTH (FT.)	EXPECTED PRODUCTION	STATUS	CURRENT DEWATERING (gpm)	EXPECTED DEWATERING (gpm)
St. Anthony	UNC	T11NR4W Sec. 19 & 30	320	NA	Development some ore as haulage ways opened	25	Few gallons minute
Marquez	Bokum Resources	T13NR5W Sec. 25	2,100	800 T/day	At about 1,700 feet trying to dewater shaft	1,200	Could be as high as 3000 but may be less
Church Rock #1E	Kerr-McGee Nuclear Corp.	T17NR16W Sec. 35	1,545	500 T/day estimated	Down concreting to 1,280'	150 (goes to Church Rock shaft)	-
Rio Puerco	Kerr-McGee Nuclear Corp.	T12NR3W Sec. 18	850	510 T/day	Shaft in developing slusher trench & sumps	500	500
Nose Rock	Phillips Uranium Co.	T19NR11W Sec. 31 T19NR12W Sec. 36	3,400	2,100 T/day	shaft #1 ~1,000' shaft #2 ~1,000' shaft #3 headframe being put in place	~1260-1400 (60-200 shafts-rest dewatering wells)	3,000-6,000
Mt. Taylor	Gulf Mineral Res.	T13NR8W Sec. 24	~3,300	4,000 T/day-4,500 T/day	shaft #1 - 3,100 shaft #2 3,130 (top of Westwater)	1,000 (wells) ~3,500 (shafts)	5,000-10,000
Old Church Rock	UNC	T16NR16W Sec. 17	900	-	Ponds under construction headframe in (reopening old mine)	not yet pumping	Expect 1,000 for 90 days then 450
NA - will connect to Roundy & Barbara J #2	Todilto Expl. & Dev. Corp.	T13NR9W Sec. 30	Shallow adit from surface decline	NA	Stripping & entry preparation in progress	-	Probably dry
Crownpoint in-situ leach	Mobil Oil	T17NR13W Sec. 9	~2,000	mil. lb. year U_3O_8 full sized plant	pilot plant under-going hydrology tests	small amount evaporating in pond	50-200 circulation

wide. The operation will produce at full production 122,500 tons of ore per year (510 T/day). Expected average ore grade is slightly over .16%. (Shaft sinking was expected to take 550-650 days.) Estimated life of the project is 8 years. To produce the 3.2 million pounds of U_3O_8 will require approximately 122.1 x 10^6 kWh of electricity. The project will disrupt about 72 acres of land. Total accumulation of waste rock produced is estimated to be 370,000 tons. Maximum employment will be 145-150 people.

Bokum's Marquez mine will mine from a Westwater ore body. It is anticipated that another shaft may be sunk near the mill site (1400-1500 foot shaft) or that a haulageway may be built from the present shaft to recover this ore. Total reserves on this property are said to be approximately 2.5 million pounds of U_3O_8. Average ore grade is expected to run about .12% U_3O_8. Mine employment will be 180-200 people. At least part of the uranium production will go to Long Island Power and Lighting.

The Phillip's Nose Rock project has announced reserves of approximately 25 million pounds of U_3O_8 (average grade about .14% U_3O_8) to be produced during the 20 year lifetime (the project is scheduled to reach full production in 1982 or 1983 and to terminate in 2002). The mine recovery efficiency is estimated to be approximately 95% of the ore in place. At this time recovery of Mo as a by-product from the ore is being considered. The Phillip's project has used rings of dewatering wells around the shaft areas to dewater the surrounding area prior to shaft penetration. There are presently three sets of dewatering wells which penetrate the 1) Point Lookout Sandstone, 2) Dakota Sandstone, and 3) Westwater member of the Morrison. The Point Lookout wells will be deepened to dewater the Gallup. This technique appears to be successful. Grouting off aquifers in advance of shaft penetration is also employed. Each shaft of the three shafts is expected to take 30 months to sink, though the present progress is behind schedule. The #1 shaft is 16' across and the #2 shaft is 14'. The transformer capacity at the mine complex was reported to be 15000 KVA. There are four levels of ore (about 150' between the lower and upper) and haulage will be below the ore bodies. It has been tentatively planned to use long-wall retreat with sand backfilling. The State of New Mexico owns the surface of Township 19 North, Range 12 West, Section 36 and the Navajo

Tribe owns the surface of Township 19 North, Range 11 West, Section 31. About 470 people will be employed at the mines and mill from 1980-1996. In 1978 a maximum of 244 people will be involved in construction. The maximum construction-operation work force will be 685 workers projected to be needed in 1980. At least part of the production at Nose Rock will go to the Nebraska Public Power District.

The UNC St. Anthony mine shaft will produce ore adjacent to UNC's open pit mine. Development is above the Brushy Basin in order to avoid mining problems due to swelling of the Brushy Basin clays. The reserves of UNC in this Laguna district property are 4.41 million tons of ore having an average ore grade of .095% U_3O_8 (8.4 million pounds of U_3O_8). When shaft mining begins the complex should produce 500,000 lb/yr. of U_3O_8. By 1990 UNC would like to achieve a production level of 7 million pounds a year from all its properties.

The Gulf's Mount Taylor mine will have a large effect on total New Mexico U_3O_8 production when it reaches its full production capacity of 1.42 million tons a year of ore having an average grade of .3% U_3O_8. The company has mapped out reserves (and drilling is continuing) of over 100 million pounds of U_3O_8 in the Westwater. The uranium occurs as coffinite and fills the sandstone pore spaces along with organic humates. The uranium is in secular equilibrium with its daughters. The uranium in the ore varies from .05 - 1% U_3O_8 with most running .1 - .5% U_3O_8. The average grade of ore is expected to be around .3%. There are significant quantities of Mo and V in the ore. A work force of approximately 800 people will be needed for the mine. Since rock face temperatures will be around 130°F special air conditioning will be necessary and workers may wear ice vests.

In order to sink the shaft Gulf found that it was necessary to drill dewatering wells to various depths around the two shafts (one 24' and one 14'). At the present time water from the shafts and from the wells is being discharged near San Lucas Dam. A 24" diameter pipe runs several miles from the mine site to the discharge point. Mine water will undergo uranium removal, radium precipitation, and clarification before it is discharged.

Mining may begin by 1979. The expected life is about 20 years.

Mine water from Mount Taylor and Marquez may provide the water for the PSNM 600 MW pumped storage facility near Seboyeta. This project will have an annual average water requirement of 2000 acre-ft.

Mobil currently has a small in-situ in field test facility set up on their Crownpoint property. Smaller ore bodies and low grade ore bodies can be recovered using this technique. Uranium (U_3O_8) which might be recovered using this method amounts to approximately 40 million pounds on the Mobil properties. However the economics of drilling to such deep depths and problems of fluid circulation, clogging due to precipitation of salts, etc. may discourage these in-situ projects. Better data will be available once the pilot project has been completed.

Mines Which Will Probably be Developed

Table VI-7 lists the mines which will probably undergo development in the coming years. Many of these projects will require several hundred miners each and will discharge from each shaft over 1000 gpm of water. The area around Crownpoint appears to be an area of special importance when considering new development projects. Several of the projects will be discussed in the following paragraphs.

Because most companies do not wish to release data publicly on their future mining plans, many new projects have probably been missed.

Conoco will begin development soon of a mine very near Crownpoint in T19N R12W Section 29. The depth of this mine will be about 2200 feet. Dewatering, depending on other mine development in the area may run to 2700 gpm or slightly more. Continental has been thinking of freezing the ground before shaft sinking. Production will be 1350 ton/day when the mine is in full production.

A large project at Crownpoint is the United Nuclear Corporation's Dalton Pass Project. A 50% undivided interest in this project has been purchased by TVA.

This project has presently about 20 million pounds of U_3O_8 reserves with an average ore grade of .1% U_3O_8. It is proposed to recover these reserves via five mining sites unless the property can be unitized in which case two production shafts may be possible. Initial production rate for each mine will be approximately 200 tons per day increasing to a maximum rate of 1200 ton a day after one year. Maximum anticipated production rate for all mines that may be operating at once is 3400 tons a day or 850,000 tons/year. Sites for these are: 1) shaft #1 - T17N R14W Sec. 13 2) shaft #2 - T17N R14W, Sec. 24 and 25, 3) shaft #3 - T17N R14W, Sec. 23, 4) shaft #4 - T17N R14W, Sec. 13, and

Table VI-7
New Mexico Probable Mine Projects

NAME	COMPANY	LOCATION	DEPTH (FEET)	DEWATERING (GPM)	EMPLOYMENT	PRODUCTION T/DAY ORE
Mobil Sec. 16	Mobil Oil-TVA	T17N R13W Sec. 16	2200	2000	250	1,200
Dalton Pass	UNC-TVA	T17N R 14W Sec. 13, 23, 24, 25	2200	4000	550	3,400
Section 30	UNC-TVA	T17N R 14W Sec. 30	2200	3000		
Canyon	UNC-TVA	T17N R13W Sec. 34	~ 2800	3000	320	~850
Borrego Pass	Continental Oil	T16N R10W Sec. 18 T16N R11W Sec. 1	2275	3000 - 6000	193	850
Crownpoint	Continental Oil	T19N R12W Sec. 29	2200	2700	NA	1350
Narrow Canyon	Pioneer Nuclear	T18N R14W T17N R14W	2450	3000	230	1400
Bernabe	Continental Oil	T12N R2W Sec. 36	~1966	6000	295	1350
Church Rock II	Kerr-McGee	T17N R16W Sec. 27	2300	6000	140	900
Roca Honda	Kerr-McGee	T13N R8W Sec. 9, 17	1675	2500	NA	600
Marquez	Kerr-McGee	Near Marquez	2000 - 2200	NA	NA	NA
Marquez #2 or haulage way from #1	Bokum	Near Bokum Mill	~2000	NA	NA	NA
JJ #2 & perhaps #3	Sohio	Near Sohio Mill	~600	Small amount	Total 350-400 in all mines	NA
Isabella	Koppen	T13N R9W Sec. 6	~250 - 450' drift from Spencer shaft	Dry	Total Sec. 6, Sec. 8 } 20	100 - 150
Ruby #2	Western Nuclear	T15N R13W Sec. 27	~ 360	Dry	20 - 40	NA
Ruby #3	Western Nuclear	T15N R13W Sec. 26	~ 360	Dry	20 - 40	NA
Ruby #4	Western Nuclear	T15N R13W Sec. 25	~ 360	Dry	20 - 40	NA

Table VI-7 (cont.)

NAME	COMPANY	LOCATION	DEPTH (FEET)	DEWATERING (GPM)	EMPLOYMENT	PRODUCTION T/DAY ORE
Church Rock 1W	Kerr-McGee	Same ore body as Church Rock #1	~1800	150 gpm shaft	NA	NA
Ambrosia Lake Sec. 10	Cobb	T14N R10W Sec. 10	400 - 700	NA	NA	NA
Ambrosia Lake Sec. 14	Cobb	T14N R10W Sec. 14	400 - 700	NA	NA	NA
P-15-17	Anaconda	Near Jackpile-Paquate	NA	NA	NA	NA
San Mateo	UNC	T13N R8W Sec. 30	Reopen old mine	NA	NA	NA
House Lake Project	Phillips Uranium Corp.	T15N R13 W Sec. 17 & 20	Shaft	NA	NA	NA
San Mateo Project	Noranda	T13N R8W Sec. 30	Shaft	NA	NA	NA
Nose Rock #2 & #3 (possibly #4, #5, #6, #7)	Phillips Uranium Corp.	T19N R12W Sec. 36 T19N R11W Sec. 30 T19N R11W Sec. 17 T19N R11W Sec. 10 T18N R12W Sec. 1	~3000-4500	max. 54,309 acre ft. all mines per year	NA	NA

5) shaft #5 T17N R13W, Sec. 30. The total project lifetime is approximately 23 years.

Each mine will have an 18 foot diameter shaft about 2,200 feet deep. Haulage will be from below the ore body. A modified room and pillar technique will probably be used. In areas of multiple ore horizons multiple stopes will be mined. Waste rock may be used as backfill.

A total of eight ventilation shafts are anticipated for a maximum ventilation rate of 250,000 acfm per shaft.

Each mine will probably initially dewater at about 2000 gpm. The maximum dewatering rate from all mines is estimated at 5300 gpm and will probably drop to 3000 gpm.

Power needs will be 27000 KVA when full production is achieved about 1985. Total daily consumption of diesel fuel will be 900 gal/day per shaft. It is estimated that 1.1 gal. of diesel fuel will be used to mine a ton of ore.

The total amount of waste rock that is expected is 2×10^6 tons. A total of 250 acres of surface will be disturbed.

At full production approximately 550 people will be employed. Maximum payroll will be 17 million dollars.

If unification of the leases is possible UNC will split out its project into two projects: the Dalton Pass project and the Section 30 project. The Dalton Pass project will have one or two production shafts and will dewater at about 4000 gpm. The new (to the U.S.) German technology of freezing the shaft area as aquifers are passed through may be used.

The Section 30 project is on Indian allotted lands. Development drilling is presently being conducted for this project. The shaft site as now planned is on the edge of the mesa above the valley floor. Expected dewatering rates are about 3000 gpm. Again this is a 50/50 project with TVA.

UNC has recently filed a mining plan with USGS to develop its property in Section 34 of T17N R13W. UNC is calling this project Canyon. Again this is a 50/50 project with TVA.

As of March 1978 5 million pounds of U_3O_8 (average grade .12%) with a cut-off of .06% U_3O_8 and a minimum thickness of seven feet had been determined. The potential for 1.7 million more pounds with an average grade of .143% U_3O_8 is believed to be present. Production of 300,000 T/yr of ore for 17 years is indicated in the plan. Vanadium and molybdenum are present in the ore. If it is not possible to achieve unification of the leases three vertical shafts 2200 to 2800 feet deep will be required, otherwise only one shaft is planned for. If three shafts are necessary dewatering rates may reach 2000 gpm per shaft. If one shaft is used total dewatering rates are predicted to be about 3000 gpm. The water will go through settling ponds, $BaCl_2$ treatment to precipitate radium, and if needed uranium removal in IX facilities. It is projected that about 320 people will be needed. With three shafts total capital investment (1978 dollars) will be \$99,500,000. Total operating costs will be \$180,000,000 with \$90,000,000 labor cost.

It appears that at least initially, ore from the UNC mining projects may be hauled to the UNC mill at Church Rock.

Another project in the Crownpoint area is Borrego Pass in T16N R10W Sec. 18 about 13 miles southeast of Crownpoint. As now projected 3 vertical shafts will be utilized: 1 production and service and 2 vents. The shaft depths will be to about 2275 feet. The development will begin with two 85 inch drilled cased shafts with a 48 inch drilled shaft in between. This 48 inch hole will be enlarged into a production shaft by slabbing down from the top and pouring a concrete liner. This technique has been or is being used at both the Church Rock mines. Dewatering wells dewatering at the rate of 1000 gpm for 300 days during shaft sinking will be utilized. Pump capacity for the mine has been designed to handle 4500 gpm with 100% backup available. It is believed that initial dewatering may run 6000 gpm dropping to 3000 gpm later. The ore body trend is 1500-2100 feet wide and 6000 feet long and runs into T16N R11W Sec. 1. The ore body is fairly extensive horizontally and three haulage levels will probably be necessary. About 850 T/day of ore is the target production capacity. Mine lifetime is predicted to be 21 years. About 193 people will be needed. The annual payroll will run \$2,520,000 in 1978 dollars.

Despite the fact that ore reserves are rumored to be well over 20,000 tons U_3O_8 on this property, Conoco has indicated that at least initially it may try to toll its ore rather than build a mill. With the ore reserves which Conoco may have a second production shaft and mill may be possible.

Depending on the results of their in-situ projects, Mobil may open a shaft mine (T17N R13W, Section 16) near Crownpoint. TVA has purchased a 25% interest in the project, but MOC will be the operator. If shaft mining activities begin, production of 1,200 tons a day of uranium from the shaft is possible. Total production as presently estimated is 10 million pounds of U_3O_8. The Mobil property includes Navajo Tribal land, Navajo allotted land, and public domain.

The mine may have a 14 foot diameter concrete lined shaft sunk to a depth of about 2200 feet. Mining in the Westwater will be from beneath the ore body using a modified room and pillar mining technique. Sand backfilling may be used. Recovery of the ore from the ore body will be about 98% efficient.

Depressuring wells will be drilled to dewater ahead of shaft sinking. If no other mines are developed in the area discharge at the time the shaft enters the Westwater Canyon Member is expected to be 2300 gal/min. Average discharge during the life of the project is estimated at 2000 gpm. If other mines are developed, discharges may be less than these. The Mobil mine dewatering will cause lowering of the water table in the Westwater and will have an impact on the water supply wells at Crownpoint.

Approximately 4000 KW of power will be required. For the extraction of 10 million pounds of U_3O_8, 3.7×10^6 gal. of petroleum fuels will be used (725 gal/day diesel; plus four months of year 780 gal/day propane in shaft heater; four months 50 gal/day diesel heating).

There will be two vent holes. Each will exhaust 100,000 acfm. Storage capacity will be for 40,000 tons of ore. About 50 acres will be disturbed.

At full production approximately 250 people will be employed at the mine. The annual payroll is expected in 1977 dollars to be $6 million. During construction 125 people will be employed.

The lifetime of the mine is expected to be 10-15 years.

The Narrow Canyon property of Pioneer Nuclear Inc. is located about 9 miles west of Crownpoint in T18N R14W and T17N R14W. There are reserves of approximately 2,877,000 tons of ore with an average grade of .12% U_3O_8 (6.9 million pounds U_3O_8), using a cut-off grade of .07. If cut-off is reduced to .05% U_3O_8 reserves increase to 8.6 million pounds. Current plans are to mine for an average grade of .12%

U_3O_8. The ore is in both the Brushy Basin and the Westwater. Unless more reserves are found mine life is estimated at eight years.

Haulage will be below the ore bodies. The pillars will be taken and waste rock may be used as backfill.

The first shaft will extend to 2450 feet and may be drilled. Two 8' diameter shafts and one 16' diameter shaft will probably be sunk. Ore production is targeted at 350,000 ton/year (1400 ton/day - 5 days a week).

Total installed power will be 9900 KW (compressors - 1650 hp, pumps 2100 hp, ventilation 1350 hp, hoists 1300 hp, slushers 750 hp).

Dewatering wells may be used. A total discharge of 3000 gpm is expected.

The total site will cover 32.2 acres. The waste dump will be on 12.6 acres and will contain 450,000 tons of waste.

Approximately 230 people may be needed.

Kerr-McGee's Church Rock II (T17N R16W, Sec. 22) contains uranium reserves of approximately 15 million pounds of U_3O_8 with an average ore grade of .19% U_3O_8. During construction 62 people are expected to be employed to sink the shaft to 2300' and during the mining period it is expected that 140 people will be employed. The mine will have a 15-20 year lifetime. The tonnage of expected waste is 761,000 tons. Surface disturbance includes 30 acres in the mine site, 24 acres for haulage roads and power lines, and 12 acres for ventilation shafts. About 6000-7000 gpm may be possible in mine dewatering. Projected production is 900 T/day. The cost of construction (1976 dollars) was estimated at 12 million dollars. The company at this time has not indicated when they may begin development on this project.

A large project which will be started soon is Continental Oil's Bernabe mine. The two 14 foot diameter shafts will be developed on T12N R2W, Section 36. The first shaft will be sunk to 1966 feet while the second shaft will extend to 1926. It is reported that the shaft areas may be frozen before shaft sinking begins.

A maximum production rate of 1350 tons per day is anticipated (422 ton/year U_3O_8). Continental has reported that the deposit contains 2,300,000 tons of ore with an average grade of .2% U_3O_8 (9.2 million pounds U_3O_8) however the author believes that the reserves are greater than this. A five year lifetime is reported in the mining plan filed with USGS, with reclamation continuing after that time. The U_3O_8 production is committed to Houston Lighting and Power.

The ore body is located in the Westwater. The trend is about 8000 feet long and 500-2000 feet wide. Some thicknesses of ore up to 80 feet occur. There will probably be three mining levels.

About 500,000 cubic yards of waste material will be produced.

The project may use three dewatering wells. The average expected total dewatering flow is 6000 gpm and the water will be brackish. Since there may be hydraulic communication between the Jackpile, Westwater, and Bluff Sandstone, other aquifers besides the Westwater could be affected.

Power will be supplied by New Mexico Public Service.

It is anticipated that a total of 295 people will be employed during maximum ore production.

Continental personnel have also mentioned that Conoco is considering building a mill at the Bernabe project.

Mines which may be developed

There are projects which are probably being considered for which the state has no information. Uranium companies usually try to hold as much information as possible confidential. However it is believed that several old mine re-entries and development of several projects in the future might be possible should there be additional reserves found, economic conditions become favorable, etc. Some of these projects are listed in Table VI-8.

Future Development vs Projected Needs

It would appear from Table VI-6 that there are enough mining projects in the planning stage that if the uranium companies develop these projects New Mexico production can achieve the projected demand level for the next five to ten years. However, until shaft sinking actually begins and mines are into production it will not be known what commitments companies will really make in terms of ore production.

Employment

Table VI-9 indicates trends in employment in uranium mines in the last three years.

TABLE VI-8

NEW MEXICO POSSIBLE MINE PROJECTS

NAME	COMPANY	LOCATION	DEPTH (FT)	COMMENTS
Church Rock #III	Kerr-McGee	North Church Rock II	~ 3,000	Status not known
L-Bar	Exxon	North L-Bar Mill	NA	Still under feasibility study
West Largo	Gulf	West of Ambrosia Lake		No plans for development at present time
Baca	Gulf	Near Quemado	NA	Found not profitable to develop at present time
North Nose Rock	Phillips	North of Current Project	~ 4,000	Phillips may be considering leaching
Diamond Tail	Union Carbide	T13NR6E Sec. 16	Shallow(pit?)	Undergoing study
Marquez	NA	T13NR9W Sec. 23	Decline	Possible re-entry of old mine
Black Jack #2	Anschutz-Cobb	T15NR13W Sec. 18		Possible re-entry
La Bajada	Lone Star	T15NR7E Sec. 9	Pit	Possible re-entry
NA	Path finder	NA	NA	NA
NA	Leonard Resources	NA	NA	Possible pit or leach
Diamond	Energy Fuels	T15NR17W Sec. 33	NA	Possible re-entry
Evelyn	Energy Fuels	T14NR11W Sec. 9	NA	Possible re-entry or new development

TABLE VI-9

Employment in Uranium Mining in New Mexico

		1975	1976	1977
Mining Underground	Miners	1,256	1,335	1,902
	Service & Support	711	1,378	1,608
Mining Open Pit	Miners	197	211	352
	Service & Support	153	168	306
Technical		140	284	380
Other		174	94	263
Supervisory		226	352	453
Total		2,857	3,833	5,264
Tons of ore produced per worker		1,045	887	800

Source: GJO-100 Series

In 1977, 5264 people were employed to produce 4,209 million tons of ore, or 800 tons of ore were produced per employee. In coming years this production ratio may decrease, (as it has recently) as more ore is produced below ground, mining conditions become more difficult, and safety regulations become more stringent; or if in-situ leaching occurs the ratio may stay about the same as the in-situ process does not require as many people. Assuming the theoretical ore "need" projections and a constant 800 ton/person ratio, employment needs are projected in Table VI-10.

From the previous data it is known that for one underground mine 550 people would be employed with a payroll of 17 million or $31,000/yr. per person, for another underground mine 250 people would be employed for a payroll of $6 million or $24,000/yr. Therefore it appears that perhaps a reasonable average salary is $25,000/yr. Payroll "estimates" are included in Table VI-10. These may be too high because of the high wages for underground miners.

TABLE VI-10

Possible Employment in Mining

Year	Employment	Payroll - Million (1977 Dollars)
1977	5264	131.6
1978	6671	166.8
1979	7604	190.1
1980	10671	266.8
1981	11849	296.2
1982	13436	335.9
1983	14082	352.1
1984	17345	433.6
1985	17690	442.3
1986	19828	495.7
1987	20567	514.2
1988	22100	552.5
1989	22199	555.0
1990	24533	613.3

Mining Costs

Mining costs for uranium are dependent upon such factors as 1) when the mine was developed, 2) ore grade, 3) depth to ore, 4) size and distribution of the ore body or bodies, 5) need for special care in mining due to shales, swelling of clays, aquifers above the ore body, etc., 6) dewatering requirements, 7) utility costs, and 8) wages for miners vs. their productivity. Traditionally pit mining has been cheaper than underground mining and hence lower grade ores can be recovered.

Table VI-11 indicates open pit mining costs in various areas of the United States while Table VI-12 indicates underground mining costs.

Number of Properties of a Given Size and Estimated Lifetime

The Grand Junction office has assembled data on the uranium reserves in New Mexico in the $50 forward cost category as to amount of ore in each property. This data has been used in this report in order to give some indication as to production capability and lifetime for each property. This data is assembled in Table VI-13. It was assumed in this table that each property would be developed as one mine. There may be cases where this will not be the case. Only those properties having an average ore grade of .05% U_3O_8 or greater were used as it was assumed that low grade ore ($<$.05) properties would be developed by leaching if this were possible.

This table indicates that for the production rates that are currently being planned for in today's new mines very few individual mines will have lifetimes of over 15 years. New properties will need to be developed each year in order to sustain growth in ore production.

TABLE VII-11

ESTIMATED CONVENTIONAL MILLING COST[1]
RANGES AND AVERAGES
BY GEOGRAPHIC AREA

	$/Ton of Ore		
	Capital[2]	Operating	Total
RANGE:			
Arizona, New Mexico, Texas	1-4	5-11	6-15
California, Nevada, Oregon, Washington	2-5	7-12	9-17
Colorado, Utah[3]	1-7	6-16	8-22
South Dakota, Wyoming	1-3	4-12	5-14
Total United States	1-7	4-16	5-22
AVERAGE:			
Arizona, New Mexico, Texas	1	7	8
California, Nevada, Oregon, Washington	2	9	11
Colorado, Utah[3]	2	9	11
South Dakota, Wyoming	1	6	7
Total United States	1	7	8

[1]As used in 1977 30-year estimate of "could" production capability—January 1977 $
[2]Forward cost as of 1/1/77
[3]Where both uranium and vanadium were assumed to be recovered only costs allocated to uranium are shown

Source: John Klemenic, "Production Capability" CJO, October, 1978.

TABLE IV-12

ESTIMATED UNDERGROUND MINING COSTS[1] RANGES AND AVERAGES BY GEOGRAPHIC AREA

	$/Ton of Ore		
	Capital[2]	Operating	Total
RANGE:			
Arizona, Nevada	29-33	28-33	61-62
Colorado, Utah[3]	1-19	22-25	23-44
New Mexico	4-19	28-45	32-64
South Dakota, Wyoming	1-11	22-34	31-39
Total United States	1-33	22-45	23-64
AVERAGE:			
Arizona, Nevada	30	32	62
Colorado, Utah[3]	4	23	27
New Mexico	13	34	47
South Dakota, Wyoming	4	30	34
Total United States	10	31	41

[1]As used in 1977 30-year estimate of "could" production capability—January 1977 $
[2]Forward cost as of 1/1/77
[3]Where both uranium and vanadium were assumed to be recovered only costs alloated to uranium are shown

Source: John Klemenic, "Production Capability" GJO, October, 1978.

TABLE VI-13

Ore Reserve Size, Possible Production Rate, and Lifetime
Using Conventional Mining Techniques

Size of Property tons of ore x 10^3	Number of Properties	Estimated Production Rate	Lifetime Years
> 8,000	19	2000 T/day	> 11
4,000 - 8,000	10	1500 T/day	7-15
2,000 - 4,000	5	1000 T/day	5½-11
1,000 - 2,000	17	1000 T/day	3-5½
500 - 1,000	9	500 T/day	3-5½
0 - 500	96	500 T/day	< 3

Resource Requirements of Mining

Uranium extraction requires commitments of energy, water, and land.

It is extremely difficult to get adequate data on energy consumption. A confidential questionnaire mailed to the industry regarding present energy consumption gave some numbers which appear reasonable and some numbers which are clearly in error. Mine plans submitted to USGS, environmental assessments, and environmental impact reports have also been used to obtain energy use numbers. The results of the study are discussed below.

The electrical energy consumption in kwh per ton of uranium ore mined is dependent upon 1) type of mine (underground or pit), 2) depth of mine, 3) development status of mine, 4) amount of dewatering required, 5) vent size and numbers, 6) any air conditioning requirements, and 7) type of equipment used in the mine. Thus there is no "typical" mine. Pits run 2-3 kwh/ton ore mined. For adits and shallow declines, 15-19 kwh/ton appears reasonable, while about 30 kwh/ton is required for deep declines. For mines around 800 feet 60-140 kwh/ton would seem to be the range. For mines at 1000 to 2500 feet 100-200 kwh/ton would appear necessary for mining. To get some idea of power requirements in 1985 a "guess" of 125 kwh/ton of ore will be made for the average since the Jackpile-Paguate complex should no longer be in production and most of the ore production will be from fairly deep mines. Assuming 14,152,000 tons of ore production for 1985 would indicate power consumption of 1769 million kwh or a need for generation of 201941 kw or 202 Mw. Assuming 80% on line generating reliability would indicate power plant capacity needs of 252 Mw to supply the N.M. uranium mining industry in 1985, assuming no "peak load" demand. No peak demand is a fairly reasonable assumption since pumps and fans run continuously and most mines run more than one shift per day.

A survey was also made to determine hydrocarbon fuel use. Again it was difficult to get reasonable answers though the survey was on a confidential basis. It would appear however that for underground mining heavy oil use runs .04-.08 gal. per ton of ore mined, that diesel use varies between 1.1 and .25 gallons per ton (the higher diesel use being where little gasoline, gas, or LPG is used), that gasoline use varies between .12-.37 gallons per ton in those facilities using gasoline, that natural gas use is between 100 and 400 cubic feet per ton and that LPG consumption is between 1.9-.05 gallons per ton. If it is assumed that the new mines will switch to diesel, including heating, then perhaps on the order of 14,152,000 gallons of diesel will be required in mining in 1985. Some natural gas demand is also seen as the old mines will not want to buy new equipment. A "guess" is made that 210 million cubic feet of natural gas may be used in 1985.

An attempt was also made to determine energy consumption in explosives. The industry reported using prill and dynamite, anfo and dynamite, water gel and anfo, and hercol/toyex. A representative number appears, when a mine is well into production, to be .001 ton of explosive per ton of ore mined.

No attempt was made to determine how much energy goes into shaft sinking. However one company sinking a shaft requiring some dewatering reported an energy consumption of approximately 317,000 kwh of electrical energy during the year that shaft sinking began.

Most of the ore mined in underground mines in New Mexico comes from ore bodies lying in the Westwater aquifer. The amount of dewatering necessary depends on 1) the age of the mine 2) the amount the mine is "down dip" in the aquifer and the transmissivity, 3) the effect of surrounding mines, and 4) any fractures in the area. Some mine operations do not have flow metering equipment on the outfall where they are discharging. Therefore it is difficult to obtain accurate numbers for gallons per minute being discharged. The "best" available numbers are given in Tables VI-5 and VI-6, and VI-7. Appendix V lists water right applications.

Some mine water is recirculated to the mine, some is sent for use in ore processing in the mills, and the rest is discharged.

Mine dewatering will drain in certain regions the Westwater aquifer; an aquifer which has represented good water quality. The dewatering will cause a cone of depression around each mine, and if there is any possibility for other aquifers (some with less desirable water quality) to penetrate via fractures, unplugged drill holes, etc. they will do so. This in turn will lower the amount of water in the connecting aquifers.

Mining can also lower the water level in domestic wells. This will probably happen at Crownpoint when mining begins there.

Mining also requires land. A "typical" above ground service area for a below ground mine requires about 30-50 surface acres for mine office buildings, change rooms, hoists, ore storage, waste storage, and mine water settling ponds. Additional land is needed for haulage roads, power transmission right of way, and ventilation shafts.

If the wastes which contain above background levels of radioactive materials or the ore move away from the mine area additional land is required. This is because ore and mine waste can cause external gamma levels to rise high enough so that continuous human occupancy cannot be permitted in these areas. In addition if buildings are built and occupied above soils containing above background levels of radium the decay product radon can move into the building and radon daughter concentrations may exceed the maximum permissible levels.

Possible Adverse Effects of Mining

Mining activities can transport toxic materials into the human environment where the materials can cause adverse effects. A person can: 1) breath in toxic particulates, (including the radioactive particulate daughters of uranium) and gases, 2) ingest the materials either by drinking water containing the released toxic elements or by eating plants or animals which have the toxic materials transferred into their cells, or 3) be affected by the externally created radiation field.

The author knows of no adequate published studies of the effects uranium mining may have on the health of the general population now or in the coming years. There is no complete data base for the amounts of toxic materials in air, soil, water, plants, and animals in areas around mining activities which are due to mining. The effects of low doses of radiation over long periods of time are also difficult to access (see source material reference 46). However it is usually felt that to be conservative the dose response curve for radiation should be assumed to be linear, i.e. any radiation will have an effect. Most of the radioactive daughters of uranium have very low permissible concentrations in air and water (Appendix IV). It is the general policy that exposure to radiation should be kept to as low as reasonably achievable.

Mining equipment emits particulates, sulfur oxides, carbon monoxide, organics, and nitrogen oxides. The expected emissions per shaft for Dalton Pass, a uranium mine project which may come on line in the next several years, are shown in Table VI-14. In addition haulage equipment to the mill will also generate emissions due to fuel combustion, and if the roads are not paved, to dust becoming airborne.

The emissions to the atmosphere of radioactive materials are perhaps of greater concern.

Mining operations release the radioactive gas radon. Most of the ores in New Mexico are in secular equilibrium. Therefore when ore, which represents an abnormal concentration of uranium, is found, the radioactive daughter products including radon are also found in abnormal abundance. Opening up the ore body and dewatering during mining allows some of the radon to diffuse into the air. While very little data is available on the average concentrations of radon in underground mine vent discharges, the best numbers available would indicate radon concentrations between 400-1500 pCi/l. (See source reference 25, 26, and 27.) At the present time mine vents are discharging approximately 6,047,425 acfm, (171,142,127 liters/min.). If 800 pCi/l of radon are in the discharge, 0.1369 Ci per minute or 197 Ci a day (71905 Ci/yr) of radon are being discharged from underground mine vents.

Table VI-15 indicates for several New Mexico mines 1977 mine vent discharges per ton of rock hoisted to the surface, and indicates the

TABLE VI-14

Possible Vehicular Emissions From Mining Equipment Per Shaft[a]

Pollutant	Emissions			
	Underground		Surface	
Particulates	.20 gm/sec[b]	2.80 tons/yr[b]	.10 gm/sec[b]	.70 tons/yr[b]
Sulfur Oxides	.20 gm/sec	2.92 tons/yr	.10 gm/sec	.72 tons/yr
Carbon Monoxide	.60 gm/sec	8.78 tons/yr	.30 gm/sec	2.20 tons/yr
Nitrogen Oxides	3.20 gm/sec	46.22 tons/yr	1.60 gm/sec	11.56 tons/yr

[a]Emissions due to diesel fuel consumption.

[b]Emissions given in grams per second are for times when vehicles are operating, whereas the tons-per-year figures reflect the schedule of operations for the year.

Source: Mining Plan for Dalton Pass

TABLE VI-15

Underground Emission of Radon per 1000 MW-YR (AFR)

Mine	Mine Discharge Cubic Feet/ton of Rock Taken to the Surface	Ci Radon Ton Rock	Ci Radon 1000 MW-YR
A	1,633,333	.036	4507
B	533,333	.012	1477
C	645,833	.014	1781
D	1,115,789	.025	3079
E	493,548	.011	1362
F	1,622,222	.037	4476
G	1,000,000	.023	2759
H	604,166	.014	1667
I	700,000	.016	1900
J	1,125,000	.025	3100
K	766,666	.017	2100
L	1,082,352	.024	2986
M	846,154	.019	2335
N	1,509,091	.034	4200
O	1,028,571	.023	2800
P	1,500,000	.03	4200

1. Mines are not named due to confidential nature of data.
2. Mines discharge ft3/ton of rock was obtained by taking total discharge per minute for each mine as measured by the State Mine Inspector and dividing by average rock production (confidential) per minute in each mine.
3. Each liter of discharged air was assumed to contain 800 pci/l of radon.
4. Ore grade was estimated at .19% U_3O_8, rock was assumed to all be ore (not quite a correct assumption) and mill recovery loss was ignored.
5. 464×10^3 lb/yr of U_3O_8 was assumed average need LWR for 30 yr. operation.
6. Therefore 1221×10^{23} T/yr of ore needs was assumed (a few mines were not calculated as they are in start up etc.).

radon emission per AFR (annual fuel requirements for a 1000 MW LWR). Assumptions made in the calculations are indicated below the table. Calculations made by the NRC Staff indicate 4060 Ci of radon per AFR. The NRC number is, considering the uncertainty in knowing radon emissions in Ci per liter, consistent with the numbers obtained for New Mexico mines.

Pit mines also discharge radon into the ambient air. For the Jackpile-Paguate the open pit areas were assumed to be 1200 surface acres, and the overburden and mine waste areas were assumed to be 1100 surface acres (see source material 19 and 30). The pit cut-off grade was assumed to be .02% U_3O_8. The radon flux was then assumed to be 50 pCi/m^2sec (see source material 29). Though no data is available, the waste piles were assumed to average .01% U_3O_8 or a flux of 25 pCi/m^2sec. Waste piles and pit areas then would emit .0213 Ci/min or 11,195 Ci/year of radon. Ore piles will also emit radon. Two hundred acres of ore stockpiles was assumed, and a flux of 500 pCi/m^2sec, in order to estimate radon emissions from the ore area as .0243 Ci/min or 12772 Ci/year. Thus approximately 23,967 Ci a year may be discharged from this large complex. (This ignores vent emissions from P-10).

Ore storage piles at underground facilities will also emit radon. A somewhat "wild guess" of ore storage area is two acres per mine site (some mines such as Sec. 30 where ore is stored certainly have more than this). There are thirty active ore producing mines excluding the Jackpile-Paguate complex. This might indicate 60 acres of ore storage for a possible emission of 3,832 curies a year of radon. There are also waste areas at each mine site. One inactive mine was surveyed by the Energy and Minerals Staff and its waste bench was found to contain 10 acres. Other mines certainly have less waste than this. If 5 acres per active mine is assumed and an average of .02% U_3O_8 is taken for the waste, then radon emission might be .0018 Ci/min or 946 curies of radon per year. It is obvious that a much better data base is needed, but it appears that significant emissions (as far as the local area is concerned) of radon are occurring due to active mining activities. Elevated radon levels have been found by EPA in the area around Ambrosia Lake. The State is presently measuring radon levels in mining areas.

If mine waste piles, open pits, and old ore storage areas are not reclaimed radon emission from these sources will continue for thousands of years. If abandoned mine shafts and vents are not tightly sealed, radon, diffusing from the low grade ore areas remaining behind, will be emitted to the ambient air as natural venting occurs. Table VI-16 lists some of the results of the calculations for radon emission.

Mining also releases radioactive particulates into the air. In dry mines ore will become airborne due to blasting, loading of ore, etc. The radionuclides will include thorium 230, radium 226, lead, and the other daughters of uranium (Appendix III). No emission factors are presently available for radioactive particulate emissions from mines. Wind transport from waste piles and ore storage piles, and trucks spilling ore will also be sources of particulate emissions.

Water transport can play a significant role in transport of waste and ore. A preliminary survey of old mines indicated movement of gamma emitting material into arroyos and its transport down gradient. Many new mines have ditches, dikes, etc. to try to eliminate this problem to some extent. However even in mines now under construction movement of waste into the lower valleys has been noted.

It appears from preliminary surveys that because of air and wind transport there are areas off fenced mine property where the concentration of gamma emitting radionuclides is sufficient to cause such excessive gamma levels that people occupying these areas continuously would receive above the maximum allowed whole body dose for unrestricted areas. The extent of this problem is unknown and warrants serious attention. In addition if buildings are built in these areas or if these soils are used for fill, the radon daughters, due to radon diffusion into the buildings, might be sufficiently high as to pose a health hazard from breathing the daughters.

If plants grow in soils containing radionuclides the plants may uptake these. Animals can then ingest these plants transferring the radionuclides into the tissues or milk of the animal.

The non-radioactive elements often associated with uranium ore in New Mexico include Se, Mo, and V. Little data is available as to the elements commonly found in the barren waste material which is a result of shaft sinking, drifting, etc. Once this material is brought to the surface, oxidation may aid in mobilization into the environment. If the non-radioactive toxic material is not contained any problems due to these wastes will continue to become worse as this material along with the radioactive material spreads in the environment.

TABLE VI-16

Possible Radon Emissions in Mining[1]

Source	Curies a Year
Underground vents	71,905
Jackpile-Paguate waste piles and pit area	11,195
Ore storage (excluding Jackpile-Paguate)	3,832
Surface Waste piles (excluding Jackpile-Paguate)	1,892
Jackpile-Paguate ore storage	12,772
Inactive underground mine ore storage and waste piles*	unknown
Inactive pit mine abandoned pit areas and waste piles**	unknown
Inactive underground abandoned mine vents*	unknown

1 Does not include pit emissions from the St. Anthony and from Haystack

* A preliminary survey of some inactive mine areas indicated waste ore piles and ore pads at all facilities, little pit reclamation, and some open vents and shafts.

** The series of pits and mine waste piles in T12N R9W, Section 9 and Section 4 have been estimated to have radon emissions of 1,051 Ci/year. A similar area exists in T13N R10W, Section 30, 25, 26, and 23.

Contamination of water is also of concern. Most mine water is sent through several settling ponds. A flocculant is added to increase settling. In most cases $BaCl_2$ is used to precipitate Ra-226 from the water and many mine operators use an IX plant to remove uranium (and in one case Ra-226 also). The results of sampling mine discharge (and some mill ponds) is given in Table VI-17. The discharge can affect ground water either from the poor quality of the discharge water or from leaching of elements in the soils before the groundwater level is reached.

Radioactive materials and other toxic materials can reach surface water by movement into drainage areas of waste and ore piles. This problem has not been adequately studied, but movement of radioactive material towards watercourses has been observed.

Mining sometimes connects aquifers due to subsidence. An example of this was the inadvertant connection made between the Westwater and the Dakota in Section 35. At the Mariano Lake mine connections are made to the Dakota during routine caving. Because of the increase in pumping requirements, mining companies try in most cases to prevent connections from occuring. If the connecting aquifer has poorer quality water, water quality will be affected.

Pumping also causes a cone of depression to occur. This too can cause inter-aquifer flows to occur if there are faults or fractures in the area. Connections can also occur due to shaft and vent failures or movement between the casing and the ground. The effects of inter-aquifer contamination are not well understood at the present time.

What effects mill tailing's sand backfilling into mines may have on water quality has not yet been fully determined. Laboratory leaching studies should be performed to insure that sand backfilling will not have an adverse effect on water quality.

When mine vents remain open, air may continue to circulate through the mine. Oxidation of elements contained in the mined out area can render these mobile. An example of this is the recovery of uranium in mine water recirculation. What effect continued oxidation has on water quality in the ore bearing aquifer is not known.

The State is beginning some groundwater studies. Preliminary studies have also been performed by EPA (source reference 43).

TABLE VI-17*

SAMPLE	COMPANY	DATE SAMPLE TAKEN	Pb-210 pCi/l	Ra-226 pCi/l	Ra-228 pCi/l	U mg/l	NH_3 mg/l	Na mg/l	Cl mg/l	SO_4 mg/l	AS mg/l	Ba mg/l	Se mg/l	MO mg/l	TDS mg/l	TSS mg/l	[illegible]
Church Rock #1 (mine)+	Kerr-McGee	10-24-77	15 ± 5	89 ± 5	0 ± 2	1.0	.024	121.9	9.3	60.6	<.005	2.13	.03	<.01	363	25.4	8.59
Church Rock (IX)+	UNC	10-24-77	9.7 ± 5.6	1.9 ± 0.8	0 ± 2	1.2	.036	144.9	24.2	67.2	<.005	.88	.094	<.01	383	-	8.52
Mariano Lake (mine)	Gulf	10-25-77	0 ± 2	0.1 ± 0.1	0 ± 2	.18	.032	48.3	53.5	1045.0	<.005	-	.002	.05	1643	-	7.77
Bluewater (mill tailings liquor)	Anaconda	10-26-77	1200 ± 100	1800 ± 100	0 ± 2	53	56.9	2118.3	3111.9	8521.6	.62	.55	.006	.16	17850	20.5	2.15
Milan (mill tailings liquor)	UN-HP	10-26-77	49 ± 8	58 ± 4	0 ± 2	44	11.23	6141.0	793.2	5531.6	2.86	<.10	51.180	72.0	17035	32	10.12
UN-HP Ambrosia Lake + mines (IX)	UN-HP	10-26-77	16 ± 7	4.7 ± 1.2	0 ± 2	1.9	.11	207	70.5	675.0	.011	.17	.407	.45	1324	<1	8.14
Kerr-McGee Ambrosia Lake+ east mines (IX)	Kerr-McGee	10-26-77	14 ± 5	4.3 ± 0.1	0 ± 2	2.6	.014	271.4	88.1	837.2	.012	.66	.036	.79	1606	2.2	8.0
Section 35 & 36 (IX)+	Kerr-McGee	10-26-77	14 ± 5	2.3 ± 0.8	0 ± 2	1.1	.03	271.4	16.7	705	<.005		.027	.62	1231	1.08	8.14
Johnny M (mine)+	Ranchers	10-27-77	33 ± 6	23 ± 1	0 ± 2	.67	.115	101.2	8.8	213.7	.011		.008	.24	520	2.6	8.35
Mt. Taylor (wells)+	Gulf	10-27-77	0 ± 2	0.2 ± 0.1	0 ± 2	.08	.098	216.2	18.6	143.5	<.005		.003	<.01	601	<1	8.7
Mt. Taylor (shaft)+	Gulf	10-27-77	10 ± 5	0.7 ± 0.6	0 ± 2	.03	.039	225.4	21.3	134.1	<.005		.003	<.01	620	23.75	8.85
UNC Ambrosia Lake mines (IX)+	UNC	10-27-77	17 ± 6	29 ± 1	0 ± 2	.32	.015	427.8	108.1	1060	<.005	.27	.268	3.20	1852	1.1	8.06
Jackpile (mine pond)	Anaconda	11-15-77	26 ± 6	220 ± 20	0 ± 2	2.6	.04	503.7	15.6	842.4	.005		.043	.545	1675	23	8.44
Marquez (shaft)+	Bokum Resources	11-15-77	0 ± 2	29 ± 4	0 ± 2	<.01	1.24	209.3	24.0	527.2	.012		<.005	.007	612	553.5	8.73
L-Bar (mill tail. liquor)	Sohio	11-15-77	1800 ± 100	180 ± 20	38 ± 10	1.1	507.37	1203	529.9	303.8	1.108		.33	.679	3205.6	371	.96
St. Anthony (pit)+	UNC	11-16-77	17 ± 5	180 ± 20	0 ± 2	2.5	.86	724.5	23.5	2151.1	.005		.019	.018	1378	168	8.18
Rio Puerco (shaft)+	Kerr-McGee	11-16-77	15 ± 5	14 ± 3	0 ± 2	.02	.49	418.6	19.8	744	.005		.004		1405	51.5	11.55
N.M. Drinking Water requirements				combined - 5							.05	1.0	.01				

*The samples were taken by the water pollution control section of the New Mexico Environmental Improvement Division of the Department of Health and Environment in the fall of 1977. Radiological analysis was performed by Eberline. All other analyses were performed by the Scientific Laboratory Division in Albuquerque. Samples were treated in accordance with EPA procedures.

+All or some of the water discharged to an arroyo at the time of sampling.

Another effect of mining is damage to structures due to blasting. Anaconda repairs those structures which company personnel feel were damaged due to blasting at the Jackpile-Paguate.

Mines are also noisy. People living close to mine vents are subjected to radon and particulate emissions from the vents, and also the noise of the fans in the vents. Fortunately many mine vents are located in areas of sparse population.

Ore trucks on the highways also pose a hazard. Not only do trucks spill ore because they are occasionally loaded too full, but they are also involved in highway accidents in which people may be killed. Companies are beginning to construct private roads for ore haulage. These roads often shorten the haulage distance and certainly make the public highways safer and reduce public road ore contamination.

In a few areas in New Mexico mining has caused subsidence. This problem will probably not occur in the deeper mines under development as subsidence will not come completely to the surface. In many mines sand backfilling will be used, in which case any subsidence at all will be minimal.

GLOSSARY OF MINING TERMS

back	The roof or upper part of any underground mining cavity.
cribbing	The construction of cribs, or timbers laid at right angles to each other, sometimes filled with earth, as a roof support or as a support for machinery. The close setting of timber supports when shaft sinking through loose ground. The timber is usually square or rectangular and practically no ground is exposed. The method is also used for constructing ore chutes.
cross-cut	A horizontal opening driven across the course of vein or, in general, normal to the direction of main workings.
drift	A horizontal opening in or near an ore body and parallel to the course of the vein or the long dimension of the ore body.
muck	Rock or ore broken in the process of mining.
open-stope method	Stoping in which no regular artificial method of support is employed, although occasional props or cribs may be used only where the ore and wall rocks are firm. The simplest open stopes are those in which the entire ore body is removed from wall-to-wall without leaving any pillars. The stoping of ore in this manner is usually confined to relatively small ore bodies, since regardless of the firmness of the ground, there is a limit to the length of unsupported span which will stand without breaking.
raise	A vertical or inclined opening driven upward from a level to connect with the level above, or to explore the ground for a limited distance above one level.
roof	The ceiling of any underground excavation. Same as the "back."
roof bolt	Long steel bolts driven into walls or roof of underground excavations to strengthen the pinning of rock strata. They are expanded by means of a wedge which opens a sleeve surrounding it.
room and pillar method	In coal and metal mining, supporting the roof by pillars left at regular or irregular intervals.
sand fill	Hydraulic or pneumatic filling, stowing. Use of sand conveyed underground by water or air to support cavities left by extraction of ore.

<u>set</u>	A timber or steel frame for supporting the sides of an excavation, shaft or tunnel.
<u>adit</u>	Nearly horizontal passage from the surface.
<u>shaft collar</u>	Supporting framework at top of shaft from which linings may be hung. The term applies to the timber, steel, or concrete around the mouth or top of a shaft.
<u>sill</u>	The floor of an opening or passage in a mine.
<u>slusher</u>	A machine used for loading coal or rock by pulling an open-bottomed scoop back and forth between the face and the loading point by means of ropes, sheaves, and a multiple drum hoist.
<u>square set stoping</u>	A method of stoping in which the walls and back of the excavation are supported by regular framed timbers forming a skelton enclosing a series of connected, hollow, rectangular prisms in the space formerly occupied by the excavated ore and providing continuous lines of support in three directions at right angles to each other. The ore is excavated in small, rectangular blocks just large enough to provide room for standing a set of timber.
<u>stope</u>	Commonly applied to the extraction of ore, but does not include the ore removed in sinking shafts and in driving levels, drifts, and other development openings.

Source: Kerr-McGee

Source Material

Chapter VI

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CHAPTER VII

MILLING

Techniques

Because so little uranium is actually contained in uranium ore as it is mined, it is necessary in order to avoid large shipping expenses to concentrate the uranium at mills located close to the mines.

The ore is hauled from the mines in trucks; or in the case of the transport of some of the ore from the Jackpile-Paguate complex, in unit trains. The ore may be stockpiled at the mill until needed or it may be unloaded into the first processing stage of the mill.

All but one of the mills active or planned for New Mexico use an acid leach. While there are some differences in each mill the general procedure is to: 1) grind the ore to separate the material so that the leachate can more easily penetrate, 2) leach the ground material with H_2SO_4 using an oxidant to render the uranium more soluble, 3) separate the sands and slimes (barren) from the uranium containing solution-usually some type of cyclone and counter current decantation process, 4) remove the uranium from the solution-usually by means of solvent extraction, 5) remove the uranium from the organic solution, 6) precipitate the uranium, and 7) wash, dry, and package the product containing uranium (usually 80-83% or more U_3O_8).

The one mill which does not use a sulfuric acid leach uses an alkaline leach. The ore is ground (but much finer) and leached (including pressure leaching). The uranium is removed from the leachate, purified using several process steps, and dried.

Mills

Mills no longer in operation include a mill at Shiprock and at Ambrosia Lake. The Anaconda mill when it began operation used an alkaline leach circuit. Later the mill switched to acid leach extraction, and recently some of the processes in the mill were changed and the processing capacity was increased. The present UN-HP mill which uses an alkaline leach is the combination of two former mills; equipment from each mill is in active use.

Data on mills in active operation in New Mexico today is given in Table VII-1. Flow diagrams for each mill may be found in the source material cited at the end of this section.

Three mill license applications have been received for mills to be built in New Mexico. Data on these mills is given in Table VII-2. In November, 1978 active construction of the Bokum mill at Marquez was about 40% complete. The site has been prepared, the footings and walls for most of the buildings are in, the leach tanks are being installed, and the counter current decant circuit is being fabricated. It is expected that the mill will be ready for active operation by the summer of 1979. About 380 people are employed in constructing the mill.

The site for the Gulf mill has been selected, but no site clearing has begun. Approximately 750 people will be needed during mill construction.

A license application for the Phillips mill at Nose Rock has just been submitted to the State.

It is also expected that a mill may be built by Conoco near the Bernabe mine to mill the ore mined from Bernabe. It is also possible that a small (perhaps semi-portable) mill will be used in the Smith Lake area to supply milling for those mines located in that area.

The need for additional mills in the Crownpoint area seems dependent upon the timing of mine development in that region. If mines are rapidly developed, at least one more mill will be needed. (The Bluewater mill should have excess capacity by the mid-1980's and the UN-HP mill may also.) At the present time there are no announced plans for a mill at Crownpoint. It is not known where Conoco will mill the ore production from its mines near Crownpoint.

Looking at facilities which may be constructed in the coming years the DOE Grand Junction Office has published a list of "production centers" in its last "Statistical Data of the Uranium Industry." Long range projections indicate the possibility for a mill at Shiprock, and another mill near Mount Taylor.

If ore bodies are found outside the San Juan Basin, if the reserves are small, semi-portable mills may be used.

Until more is known as additional drilling is performed, it is difficult to predict how many new mills may be built in New Mexico

TABLE VII-1

NEW MEXICO MILLS NOW IN OPERATION

COMPANY	LOCATION	CAPACITY T/DAY	OPERATING T/DAY	START UP	EXPECTED LIFETIME	RECOVERY %	GRADE %	INPUT WATER GPM	ELECTRICAL CAPACITY	FUEL* REQUIREMENTS	EMPLOYMENT	TYPE	BY-PRODUCTS
Sohio Oil - Reserve Oil	Seboyeta	1660	~ 1550	1976	10-15 years	93	.18	500	7500 kw	3100 $\frac{\text{gal.}}{\text{day}}$ of #2 diesel	71	acid	
Kerr-McGee Nuclear Corp.	Ambrosia Lake	7000	~ 7000	1958	NA	97	historically .2	~2500		136,986 $\frac{\text{ft.}^3}{\text{day}}$ natural gas	244	acid	Mo
UN-HP	Milan	3500	~ 2550	1958	1986?	NA	.15	183	7000 kw	1,696,712 $\frac{\text{ft.}^3}{\text{day}}$ natural gas+	151	alkaline	V
Anaconda	Bluewater	expanded to 6000	~ 6000	1953	1985?	> 90	~ .15	NA		867,945 $\frac{\text{ft.}^3}{\text{day}}$ natural gas+	376	alkaline now acid	
UNC	Church Rock	4000	~ 3500	1977	NA			723-1200	NA	5479 $\frac{\text{gal.}}{\text{day}}$ #6 fuel oil	117	acid	
UNC	Ambrosia Lake	IX only	-	-	-	-	-	-					

*excludes space heating
+engines can use diesel

TABLE VII-2
NEW NEW MEXICO MILLS WITH LICENSE APPLICATIONS

COMPANY	LOCATION	CAPACITY TON/DAY	START UP	EXPECTED LIFETIME	RECOVERY %	ORE GRADE %	ELECTRICAL	FUEL OIL REQUIREMENTS	COAL REQUIREMENTS	WATER	EMPLOY-MENT	TYPE	BY PRODUCTS
Bokum Resources	Marquez	2,200 expand 3,000?	Summer 1979	20 years	96	.12	31.5 $\frac{\text{kwh}}{\text{ton ore}}$	2.47 $\frac{\text{gal.}}{\text{ton ore}}$	none	500 gpm	45	acid	none
Gulf Mineral Resources	San Mateo	5,000	Late 1981	20 years	95	.32	38 $\frac{\text{kwh}}{\text{ton ore}}$	.3 $\frac{\text{gal.}}{\text{ton}}$	120 $\frac{\text{tons}}{\text{day}}$? may use fuel oil	1181 gpm	140	acid	maybe
Phillips Uranium Co.	Nose Rock	2500 2750 (design) expand. 1983-1985 5000	early 1980's	20 years	96-98	.14	NA	.16 $\frac{\text{gal}}{\text{ton}}$ plus propane for dryer	none	1000 gpm	40	acid	Mo maybe

after 1990 or 2000. If no new reserves are found, there will probably be no new mills constructed as the ore supply will be decreasing rapidly.

Employment

Table VII-3 indicates trends in employment in uranium mills in the last three years. To estimate employment needs in future years a processing efficiency of 4100 tons per person will be assumed. The employment predictions are given in Table VII-4.

TABLE VII-3

Employment in New Mexico Uranium Mills

	Year		
	1975	1976	1977
Operations	286	488*	362
Maintenance	207	278	306
Technical	50	92	71
Other	214	51	161
Supervisory	95	137	121
TOTAL	852	1046	1021
Ton ore processed per person	3504	3251	4122

*Construction workers included

TABLE VII-4

Predicted Employment in Milling in New Mexico

Year	Predicted Employment
1978	1302
1979	1484
1980	2082
1981	2312
1982	2622
1983	2748
1984	3384
1985	3452
1986	3869
1987	4013
1988	4312
1989	4331
1990	4786

Resource Requirements

Uranium milling requires commitments of energy, water, and land.

As with uranium mining it has been difficult to get adequate data on energy consumption. Energy consumption will vary depending upon the process used, whether the water supply and/or tailings have to be pumped uphill and whether there is an associated sulfuric acid plant whose excess heat generation can be used for process heat.

From the data now available it would appear that approximately 30-40 kWh of electrical energy is required to process one ton of ore. If an average of 35 kWh is assumed, in 1985 assuming all uranium production is via conventional mining and needs are as indicated in Table IV-4, approximately 495,320 thousand kWh of electricity will need to be generated. For continuous usage this would indicate 56543 kw or 56.5 MW of power would be required. For 80% on line generation this would indicate a need for 70.7 MW of installed electrical capacity to meet milling electricity needs. Adding mining needs of 252 MW would indicate a need for installed generating capacity of 323 MW to meet the needs of the uranium industry in 1985.

Hydrocarbon needs due to milling are difficult to access. It is assumed that the old mills will continue at their present usage and that Bokum, Gulf, and Phillips will consume coal and fuel oil as stated in their license applications. If the Bernabe and possible Crownpoint mills both use diesel then approximately 13,440 gallons of diesel per day may be consumed by those two mills. However, some coal may be used for process heat.

An acid leach type mill needs for every ton of ore processed between 1 and 1½ tons of water. An alkaline mill needs slightly less than this; since the only alkaline mill in New Mexico is the UN-HP mill, average water requirements will be estimated at 1.25 ton water per ton of ore processed. Estimated water requirements are given in Table VII-5. This of course does not include water needed for cooling at the electrical generating plant that is supplying the electrical energy.

One of the most complete analyses of man-power, water consumption, fossil fuel, and chemical consumption for a mill is contained in the recent Gulf Mineral Resources mill license application. Not only does this application consider resource commitments during operation, but

TABLE VII-5

Water Requirements for Milling in New Mexico

YEAR	GALLONS X 10^6/YR.	ACRE-FT./YR.
1978	1606	4930
1979	1831	5621
1980	2570	7890
1981	2853	8759
1982	3235	9931
1983	3391	10410
1984	4177	12823
1985	4260	13078
1986	4775	14659
1987	4953	15206
1988	5322	16338
1989	5345	16409
1990	5907	18134

resource needs to construct the facility are also given. Tables VII-6 and VII-7 indicate these commitments for this mill.

The Gulf Mill facility it is estimated will disturb 900 acres of ground, including: the mill site, 200 acres; the roads serving the mine-mill areas, 50-55 acres; the tailings emplacement area, 500 acres; and the tailings pipeline and associated road, 42 acres. A total of 1500 acres will be fenced off. Smaller mills disturb less acreage of course.

Once the mill is no longer active it should be decommissioned. The buildings should be removed, and the ore pads , evaporation ponds or retention lagoons cleaned up to where only a small level of radiation above background is present (interim land cleanup criteria have been issued by NRC). Then the land can be seeded and hopefully returned to productive use.

However because of the long lifetime of the radionuclides present in the mill tailings piles, tailings piles must be isolated for thousands of years.

Data on the inactive tailings piles presently in New Mexico is given in Table VII-8. The final rehabilitation procedure for these piles has not been determined. It may be that these piles will have to be moved and placed in another location. Data on present New Mexico tailings piles is given in Table VII-9 and data on New Mexico tailings piles for which mill license applications have been received are given in Table VII-10.

The resource commitments which will have to be made in decommissioning a mill and rehabilitating a tailings pile have not been fully determined. It has been estimated that to demolish and bury the main mill building and 11 smaller structures at the defunct Edgemont S.D. mill may cost $230,000. An additional $250,000 will be needed to decontaminate off-site areas. Costs of rehabilitating the 2.3 million tons of tailings and the contaminated sub-soil in a suitable manner run from 10.8 to 19 million dollars. Clearly many man-hours of work, and thousands of gallons of diesel fuel will be needed for this task.

Since there are presently five inactive tailings piles in New Mexico, five active mills and tailings piles, three mills which are being built or will soon be built, at least one mill (and perhaps one portable mill) which will probably soon be built, and a potential for

TABLE VII-6

Resource Commitments for the Construction of a 5000 ton a Day Uranium Mill and Tailings Emplacement Facility

Mill

electrical	-	30,000 kWh
gasoline	-	55,000 gal.
diesel	-	490,000 gal.
manpower	-	810 man-year
time	-	18 months

Tailings Dam - 1st stage

diesel	-	330,000 gal.
gasoline	-	16,000 gal.
manpower	-	16 man-years

Tailings Dam - Operation and Further Advancement of Dike Height

manpower	-	3,000 hours per year
diesel fuel	-	42,000 gal. per year
gasoline	-	1,700 gal. per year
lube oil	-	700 gal. per year
grease	-	500 pounds per year

Electricity for sump pumps - 65,000 kWh per year

Electricity for return water system - 130,000 kWh per year

Source: Gulf Mount Taylor Mill license application

TABLE VII-7

Resource Committed for a 5000 ton a Day Mill

ITEM	PER DAY	PER YEAR
electricity	1.6×10^5 kWh	6×10^7 kWh
water (process)	1.7×10^6 gal.	630×10^6 gal.
water (potable & sanitary)	4,375 gal.	1.6×10^6 gal.
sulfur	150 tons	55,000 tons
sodium chlorate	40 tons	15,000 tons
ammonia	3.1 tons	1,000 tons
sodium carbonate	40.8 tons	15,000 tons
hydrogen peroxide	3.4 tons	1,200 tons
lime	35 tons	13,000 tons
Alamine 336	23 gallons	8,400 gallons
isodecanol	23 gallons	8,400 gallons
kerosene	710 gallons	$.26 \times 10^6$ gal.
flocculant	1 ton	350 tons
diatomite	1.5 tons	550 tons
coal	120 tons	44,000 tons
#2 fuel oil	1,200 gal.	$.44 \times 10^6$ gal.
ore	4,200 tons	1.4×10^6 tons
uranium	13 tons	4,300 tons
manpower	126 man-days	126 man-years

Source: Gulf Mount Taylor Mill license application

TABLE VII-8

Inactive Tailings Piles in New Mexico

COMPANY	LOCATION	AREA ACRES	HEIGHT (FT.)	TONS TAILINGS	STATUS
Foote Mineral	Shiprock	{26 {46	14-40 15 average	1,700,000	operated 1954-1968 partly stabilized
Homestake	Milan	48	NA	1,218,000	operated 1958-1962 not stabilized
Phillips	Ambrosia Lake	91	3 to 33	2,684,000	operated 1958-1963 not stabilized
Anaconda	Bluewater	24	NA	584,184	operated 1953-1956 partly stabilized
Anaconda	Bluewater	51	NA	180,849	partly stabilized

TABLE VII-9

Active Tailings Piles in New Mexico (Dec. 1977)

COMPANY	LOCATION	POND (ACRES)	DRY (ACRES)	TOTAL (ACRES)	MAX. HEIGHT (FEET)	MILLION TONS TAILINGS	ESTIMATED RADIUM (CURIES)
Kerr-McGee	Ambrosia Lake	70	195	265	100	23	12,850
United Nuclear-Homestake Partners	Milan	25	80	105	75	16.2	5,660
Anaconda	Bluewater	107	159	266	21	13.6	7,600
Sohio-Reserve	Seboyeta	38	22	60	35	.54	247
United Nuclear	Church Rock	18	6	24	8	.01	2.6

Source: Radiation - Health and Environment, State of New Mexico

TABLE VII-10

Proposed Tailings Sites for which license applications have been received*

COMPANY	LOCATION	AREA (ACRES)	COMMENTS
Bokum	Marquez	315	covers two major drainage areas, above grade, not completely lined.
Gulf	San Mateo	500	in somewhat of a natural basin, above grade, not completely lined-some fractures in area.
Phillips	Nose Rock	470	sands and slimes will be separated in two different above grade unlined disposal areas.

*May be revised during license approval.

at least three more large mills to be constructed, the total cost for restoration, both resource-and money-wise, will be large and should be examined in more detail than is possible in this paper.

If the area is not restored movement of radionuclides into the environment will occur. Already at least at one inactive tailings pile gamma radiation levels outside the fenced area of up to about fifty times natural background have been noted. Land which has become excessively contaminated should be decontaminated or else removed from human use (including grazing, etc.).

It is also possible that if a tailings pile is not stabilized so that radon emission is reduced to levels similar to the natural radon flux, radon and radon daughter levels in the ambient air around the immediate area of a pile may be high enough to warrant exclusion of people in a "buffer" zone around the pile.

Economic

The uranium industry has faced steadily rising costs in recent years. For example the Kerr-McGee 7000 ton a day mill at Ambrosia Lake cost $18 million to build in 1958. Today this facility would probably cost slightly over 100 million dollars.

Phillips has estimated development costs for their new mine-mill complex at $61 million (2500 ton/day of production). For operating costs in 1982 Phillips estimates for their Nose Rock property that it will cost $25/ton to mine this ore and $7.90/ton to mill the ore. Construction and operating costs do not include the costs of exploration and development which is necessary before a mine can be planned.

For their Mariano Lake mine, Gulf in its mining plan submittal to U.S.G.S. lists the following costs: mining $22.85/ton, haulage $5.07/ton, and milling $8.82/ton. Gulf indicates total costs at $54.32/ton plus royalty.

The DOE office at Grand Junction has also estimated milling costs for various regions. Their estimates are shown in Table VII-11.

Environmental Effects of Milling

Uranium mills have various types of emissions to the atmosphere. The use of diesel, coal, or natural gas fuels causes production of combustion products. These products are usually emitted from stacks

TABLE VII-11

ESTIMATED CONVENTIONAL MILLING COST[1] RANGES AND AVERAGES BY GEOGRAPHIC AREA

	$/Ton of Ore		
	Capital[2]	Operating	Total
RANGE:			
Arizona, New Mexico, Texas	1-4	5-11	6-15
California, Nevada, Oregon, Washington	2-5	7-12	9-17
Colorado, Utah[3]	1-7	6-16	8-22
South Dakota, Wyoming	1-3	4-12	5-14
Total United States	1-7	4-16	5-22
AVERAGE:			
Arizona, New Mexico, Texas	1	7	8
California, Nevada, Oregon, Washington	2	9	11
Colorado, Utah[3]	2	9	11
South Dakota, Wyoming	1	6	7
Total United States	1	7	8

[1]As used in 1977 30-year estimate of "could" production capability—January 1977 $
[2]Forward cost as of 1/1/77
[3]Where both uranium and vanadium were assumed to be recovered only costs allocated to uranium are shown

Source: John Klemenic, "Production Capability," GJO, October 1978 connected to the combustion equipment. The quantity of the pollutant emitted depends on the type of fuel burned, amount of fuel consumed, and any collection devices. For example, Gulf plans on installing a baghouse and lime scrubber to remove particulates and SO_2 from the off-gas of its coal burning equipment. Those mills having a sulfuric acid plant will have emissions of sulfuric acid mist and other sulfur compounds. The extent of these emissions depends on the efficiency of the catalysts used in the plant, and the efficiency of the mist eliminator. If these are in good condition emissions should be fairly low. Sulfuric acid mist is also emitted from the leaching circuit. Scrubbers and mist eliminators can be used to reduce this emission to extremely low levels. Some organics are emitted during solvent extraction. Use of efficient combustion equipment, and scrubbers and mist eliminators where applicable will reduce the airborne non-radioactive emissions from a mill to very low levels.

Radioactive particulate emissions occur in a mill in the dry grinding circuit, and in the yellowcake drying and packaging process. High energy venturi scrubbers followed by mist eliminators can be used to reduce these emissions to very low levels. Not all New Mexico mills have such equipment in operation.

A small amount of radon will also be emitted in the grinding operation and in the leaching circuit. Autogenous grinding reduces the emission of radon in this circuit. Emission of radon during milling is low enough such that levels outside the plant area due to this emission should not pose any health hazards.

Fugitive emissions can result from particles from ore piles becoming airborne during gusty winds. Levels of radioactivity in excess of background have been found for several feet below inactive mill's ore storage piles, indicating migration of the radionuclides downward. Water run-off during rainstorms can transport ore along the ground surface. A mill can be designed with ore pads, ore wind breaks, and ponds to catch rain run-off. A few New Mexico mills do have run-off catchment, but no New Mexico mill today has all ore on special ore pads, nor do New Mexico mills have wind breaks installed. Much of New Mexico's ore is mined wet, however, wind transport of ore piles has been noted.

A mill also has sanitary wastes, wastes from washing the plant and worker clothes, and shower water. Sanitary waste disposal must follow regulations for proper disposal of sanitary wastes. Shower water and water from wash down of the plant, washing worker clothes, etc. should be sent to the tailings pond as this water will contain radioactive material.

The largest discharge from a mill is the spent process material. Since so little uranium is in the ore, almost everything which goes into the mill is discharged from the mill as tailings. These tailings will contain all the spent chemicals, process water, and the sand-slime mixture which once was ore. At the end of 1977 there were approximately 60 million tons of tailings in New Mexico. If the $50 forward cost ore reserves are exploited there will be an additional 547 million tons of tailings!

Most of the original radioactivity that was in the ore is also discharged with the tailings. After a short period, the short-lived daughters decay leaving thorium-230 as the parent radionuclide in the decay chain. Thus about 70% of the activity, excluding the uranium which was not recovered and also goes to the tailings, will remain in the tailings for thousands of years. Most of the daughters have low permissible concentration limits in air and water (Appendix IV). Therefore a great deal of effort must be made to insure that the tailings do not move into the environment for thousands of years.

Other toxic materials in the tailings can include trace elements such as Se, and the organics which were used in solvent extraction.

Movement of tailings can occur in many ways. Tailings piles can seep. Any element that is contained in the seepage will then escape. In acid type circuits much of the thorium goes into solution during the leaching process. Elements in solution can be noted from the sampling data given in Table VI-17. Excessive levels of Se have been found in well water near the UN-HP mill, however soils in the general area of the tailings also contain Se.

Tailings dams can also erode due to the action of flowing water, and surface run-off can carry tailings into the surrounding area. This is quite evident at the old Phillips' pile where there were breaks in the dike until they were recently fixed. The roadways at the Phillips' pile have also been found to be channeling water run-off and hence bringing tailings downward.

Tailings pipes can break. A break at the UNC mill deposited tailings on the ground near the tailings pile. When the tailings pipe broke at UN-HP the break eroded the dike area, causing loss of the entire cell into the surrounding area.

Tailings can also move due to high winds. Sand dunes on the down wind side of tailings piles and levels of radioactivity in excess of background in these areas testify as to the effectiveness of this type of transport.

If tailings move into surface water drainages the water becomes contaminated.

The gas radon also diffuses from tailings piles. When radium decays into radon it appears, depending upon the matrix which the radium is in, that some of the radon becomes free to diffuse as a gas. If the radon is close enough to the surface so that it does not decay into its non-gaseous daughter before reaching the atmosphere, it diffuses out and becomes airborne. Radon will continue to diffuse from a pile for thousands of years unless a suitable cover is placed on the pile so that the radon is contained.

If it is assumed that the radon flux from the wet part of the tailings pile is 25 pCi/m^2sec and that the radon flux from dry tailings is 500 pCi/m^2sec then approximately 48,800 Ci each year are emitted from New Mexico tailings piles. Since 6,780 tons of U_3O_8 were produced in 1977 this represents an emission of 1670 Ci per AFR (annual fuel requirements) for a 1000 MW light water reactor. This emission can be compared with the radon emissions from mining given in Table VI-16. While it does not appear that at the present time mill tailings emit as much radon as do mining activities, emissions from uncovered mill tailings will continue for thousands of years.

If plants grow on mill tailings or if mill tailings move into areas where plants grow, the plants can uptake the radionuclides. If cows graze on the plants, (cows may also ingest contamined dirt along with the plant) the radionuclides move into the tissue and/or milk of the cow.

One technical study (source reference 23) compared the natural runoff of Ra-226 in rivers and streams with the amount found in a typical mill tailings generated by milling the uranium needed to fuel one billion watt electric-year of nuclear energy. It states, "Approximately 150 Ci/ yr. of Ra-226 are found in the U.S. watershed runoff due to natural leaching. The tailings pile generated by the production of only 1 Gwe-year of nuclear generated electricity contains an amount comparable to this in a very precarious and erodible form. Thus by a measure of potential perturbation of background radiation in water supplies, past practices for storage of the mill tailings appear rather precarious by comparison to plans for the emplacement of high level wastes."

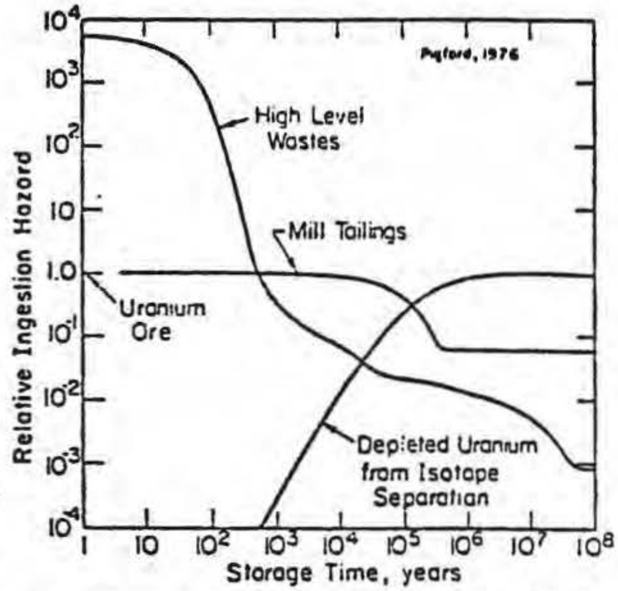
While it is difficult to predict on the long term basis how radionuclides may be transferred to man, and while a calculation of an ingestion hazard may be somewhat misleading, it is interesting to compare relative ingestion hazard vs. storage time in years of high level wastes, mill tailings, uranium ore, and depleted uranium. Such a calculation has been performed by Pigford and Choi and is shown in Figure VII-1. This indicates that after about 600 years the relative ingestion hazard for mill tailings is more than for high level wastes.

Studies have been started to investigate the levels of radioactivity (including radon) in the Ambrosia Lake area. Preliminary data collected for a short period of time by EPA indicated elevated radon levels. Little data has been collected on the Th-230 ambient levels, which may pose a possible hazard as the MPC for Th-230 in air is very low. As the results of the studies by the State of New Mexico, Argonne, Battelle, etc. become available more will be known as to the immediate hazards which the uranium industry may be creating. However, even these studies will not give an adequate data base. Far more data on radon in active and inactive mine vent exhausts, general external gamma dose levels, radon flux from ore piles, waste piles, mined out pit areas, movement of ground water, etc. is needed. A better understanding is needed of dose from food pathways.

However it would appear that present emissions due to mining and milling represent some of the most significant radioactive emissions in the whole nuclear fuel cycle.

At present the Nuclear Regulatory Commission position on the proper technique for tailings disposal as stated by Leland C. Rouse is:

FIGURE VII-1



Relative ingestion hazard of solid residuals from light-water reactor fuel cycle (U Fuel, 0.5% of U and Pu in high-level waste).

Source: Reviews of Modern Physics, January, 1978.

"Based on recent evaluations of tailings management alternatives for new mill proposals within our jurisdiction we would encourage the agreement states to consider the elimination of surface disposal of tailings, regardless of dam construction materials proposed. The major reason for requiring some form of below grade disposal system is that such disposal clearly provides greater assurance that the buried tailings will not be disturbed by man or by natural phenomena over the long term."

So far the State of New Mexico has failed to follow this suggested position by NRC. Therefore at the present time it is uncertain what policies will be followed, and hence what the long term hazards from tailings piles may be.

The Nuclear Regulatory Commission has also issued a position for interim land cleanup criteria. This position indicates that it is desirable to reduce the gamma dose rate to 5 μR/hr above background, and in all cases radon flux above background "should not exceed a flux equivalent to .02 Working Levels inside a potential structure on the decommissioned site and gamma dose should not exceed 20 μR/hr above background."

Applying the criteria of cleanup to 20 μR/hr above background to mine wastes, old ore storage pads, haulage roads, and general soil contamination from wind and water transport may result in the necessity for a very large clean up effort throughout the Grants Mineral Belt.

Source Material

Chapter VII

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6. Statistical Data of the Uranium Industry GJO-100(78), GJO-100(77), GJO-100(76), Grand Junction Office, Grand Junction, Colorado.

7. Uranium Mining and Processing, Kerr-McGee Corporation.

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9. Sohio L-Bar Mill - Mill License Application to the State of New Mexico.

10. Kerr-McGee Ambrosia Lake Mill - Mill License Application to the State of New Mexico.

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12. Anaconda Mill - Mill License Application to the State of New Mexico.

13. UNC IX Plant - License Application to the State of New Mexico.

14. Bokum-Marquez Mill - License Application to the State of New Mexico.

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17. Draft Environmental Statement, Crownpoint Uranium Mining Project. TVA, Department of the Interior.

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24. "Staff Technical Position Fuel Processing and Fabrication Branch Interim Land Cleanup Criteria for Decommissioning Uranium Mill Sites," Nuclear Regulatory Commission, May, 1978.

25. Memo from Leland C. Rouse to G. Wayne Kerr.

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37. Water Rights applications to the State of New Mexico.

Appendix I

Calculations of U-235 in Tails

Assume all tails at .25% U-235; assume no net domestic production was exported for enrichment. Assume all AEC U_3O_8 purchases (beginning in 1956) from overseas (47,435 tons) and Canada (70,780 tons) and U.S beginning 1947 to 1971 (173,665 tons) to have been enriched to 90% U-235. Assume the rest of the U.S production to 1978 (139,435) to be enriched to 3% U-235: It is known that uranium comprises 85% of U_3O_8, so the uranium in the highly enriched = .85 x 291880 tons = 248098 tons of which 1736.69 tons is U-235 (U-235 is .7% of the total U). It can be calculated that for 90% enriched uranium and .25% tails that 36% of the U-235 remains in the tails; therefore for the highly enriched portion there are 625.2 tons U-235 in tails.

For 139,435 tons U_3O_8 enriched to 3% U-235 there will be 118,520 tons of U or 829.6 tons of U-235. It can be calculated that for 3% enrichment and .25% tails that 30% of the uranium -235 remains in the tails or 248.9 tons U-235 for a total of approximately 874.1 tons of U-235 in the tails. This is the same amount of U-235 found in 146,906 tons of U_3O_8. While these assumptions may not be entirely correct, order of magnitude numbers should be indicated.

Annual U-235 needs vs. U-235 in tails can be computed using 1978 GJO data. This is given in Table A.

As can be seen if the U-235 in the tails were recovered this would have the effect of increasing the uranium supply by "several years" worth.

TABLE A

Year	Tons U_3O_8	Tons (U)	Tons U-235	Tons U-235 Tails
1978	18600	15810	110.7	26.6
1979	21200	18020	126.0	30.2
1980	28100	23885	167.2	40.1
1981	31200	26520	185.6	55.7
1982	33300	28305	198.1	59.4
1983	34900	29665	207.7	62.3
1984	40300	34255	239.8	71.9
1985	41100	34935	244.5	73.3
1986	43000	36550	255.8	76.7
1987	44600	37910	265.4	79.6
1988	44500	37825	264.8	79.4
1989	44700	37995	266.0	79.8
2000	45600	39525	276.7	83.0

.2% tails through 1980 (24% U-235 in tails of total U-235)
.25% tails thereafter (30% U-235 in tails of total U-235)

Appendix II

Preliminary Remarks on the Feasibility of Increased Employment in New Mexico Through Development of Nuclear Fuel Fabrication and Waste Processing Plants in the State.

Introduction

New Mexico at the present time mines and mills approximately 46% of the uranium ore produced and processed in the United States. Moreover, New Mexico has in the $30 forward cost category 53% of the U.S. ore reserves (U_3O_8). While about 3,833 people are employed in mining and 1,046 people are employed in milling in New Mexico, further job opportunities would be available if commercial refineries to produce UF_6 feed, U-235 enrichment facilities, and fuel fabrication plants were operated in the State. If fuel reprocessing technology is developed to extract valuable material from spent fuel rods a reprocessing and reconversion facility would also provide increased employment.

Fuel Fabrication

At the present time, yellowcake (ca. 85% U_3O_8) is shipped from uranium mills in New Mexico to refineries which convert the uranium oxide into UF_6. This material is then used as feed for the DOE gaseous diffusion plants located at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. In this set of diffusion plants, the concentration of U-235 is increased from .7% to approximately 3% in the total uranium since LWR (light water reactors) require about 3% "enrichment" (i.e. U-235/total U) in order to operate. The depleted feed stream (about .25% U-235 in the uranium) is stored and the enriched uranium for the commercial reactor fuel utilization program is sent to commercial conversion and commercial fuel fabrication facilities.

Presently, the gaseous diffusion plants provide about 17 million SWU's (a SWU is the standard measure of separation work). Improvements in the system will allow the operation to reach 23 million SWU per year, while updating the electrical equipment will allow for 28 million SWU. The improvement and electrical utilization programs are planned for completion in 1981. At this time, the plants will use approximately 7,400 MW of electrical power.

In addition to their large power requirements, the gaseous diffusion systems are going to need intensive maintenance if they are to maintain their 28 million SWU capacity. The original Oak Ridge plant began operation in 1945. The Paducah facility began production in 1954, while Portsmouth achieved production in 1956. These facilities are not only old but they are also very large. For example, they contain 400 miles of process piping with over 20,000 valves and more than 5,000 operating motors and compressors. Maintenance for these old facilities is going to be expensive.

In order to increase the nation's capacity for U-235 enrichment, it has been proposed to build a gas centrifuge complex at Portsmouth. The centrifuge process requires only about 7% of the power needed to operate a gaseous diffusion plant of the same capacity. However, centrifuge plants are expensive and have not yet operated successfully in the U.S. Costs for a 9 million SWU a year facility many run between 4-8 billion dollars. While experimental production type centrifuges have been operating since 1970, a substantial effort is going to be required to commercialize the technology and to establish an industry capable of supplying the components needed for these plants.

The gaseous and centrifuge systems make use of the physical property of the U-235 being slightly less in mass than the U-238 from which it is separated. However, the amount of light energy at certain frequencies (light waves or photons) which each (U-235 and U-238) will absorb can be very different. In other words, the differences in atomic structure can be utilized in a type of separation technique.

In early February, G.W. Cunningham, Acting DOE Program Director for Nuclear Energy, told a House Subcommittee that the advanced isotope-separation program was "making good progress and offers tremendous promise of meeting our future energy needs." He outlined three technologies: (1) molecular process, (2) atomic vapor process, and (3) plasma separation which uses ion cyclotron resonance. Mr. Cunningham testified that selection of a process and operation of an engineering demonstration plant was expected by the mid-1980's. It is also expected that, should the engineering demonstration be successful, about 9 million SWU will be added on to the existing systems using the advanced technology and will be available by the early 1990's to reduce tails to .1% U-235.

Probably the most promising of the three technologies is the molecular process by means of which slight enrichment of U-235 in natural uranium was first achieved in 1976. In this process, uranium is first converted (or the present off gas streams are used) to UF_6 (the same material which is used in diffusion and centrifuge plants). Then an infrared photon selectively excites the molecules of 235 UF_6 to a much greater degree than the molecules of 238 UF_6. Once the 235 UF_6 is excited an ultraviolet photon is used to selectively decompose the excited 235 UF_6. The products of the decomposition are 235 UF_5 and F. The 235 UF_5 can then be precipitated from the mixture, hence removing U-235 from the initial gas streams. To aid in the selective excitation of the proper molecules (the absorption spectrum of the molecule is simplified) the UF_6 can be cooled by expanding it through a nozzle. This technique requires several types of equipment. There are infrared photon generators, (i.e. lasers which produce a very discrete energy in the infrared), ultraviolet photon generators (lasers emitting discrete energy levels in the ultraviolet), flow ducts, and compressors. The same special materials as required in diffusion plants in the piping network will be used, because of the corrosive UF_6 and fluorine.

If this system can be developed, the construction costs for the facility are projected to be much less than for comparable diffusion or centrifuge facilities. It has been estimated that in 1978 dollars a 9 million SWU facility would cost 500-800 million dollars (excluding the associated UF_6 production facility).

Although lasers and compressors require power, total power needs will be much less than for the present enrichment facilities. Studies indicate 50-200 MW as the total power needs for 9 million SWU laser isotope separation unit. Thus huge requirements for power are not imposed on the region in which the facility is located. Since power needs are less, cooling needs are also less. Reject temperatures may be high enough that commercially available "fin-fan" air cooling will be possible.

Land requirements are also modest. The enrichment facility can fit into a space approximately 600 x 600 feet.

The 9 million SWU complex is envisioned to employ 500-700 people of various skill levels. People will also be needed to construct the necessary equipment and the plant itself.

Environmental degradation from such a facility should be minimal. Power lines will have to be brought in or a small generating facility located at the site. The combination of compressor and electric power generation needs might be met using a small low BTU coal gasification plant.

Escape of uranium should be minimal as it would be expected that all ducting and other transfer mechanisms would be leak tight. Uranium in itself possesses little hazard in terms of radiation exposure. Should UF_6 escape, it should cool and condense at ambient temperatures and should be contained within the building.

There appears to be significant need for advanced separation facilities. As the world's electrical generating needs increase, more and more of the base load requirements will be met with nuclear, and world-wide enrichment needs are going to increase. Also the world's supply of uranium may be limited. Thus increased enrichment capacity will be needed not only to provide for new reactors coming on line, but also to allow for a reduction in the amount of U-235 left in the residual depleted stream and to recover U-235 left in the present depleted tails stock.

It also appears that replacement of the present gaseous diffusion plants would allow for cheapter separation. The power bill alone (264 MW per million SWU vs. 8-22 per million SWU) would seem to justify this replacement. In addition, maintenance costs on the new laser isotope separation units should be much less than for the gaseous diffusion units.

Therefore, laser isotope separation techniques could quickly replace gaseous diffusion and centrifuge processes once the technique has been demonstrated on the pilot plant scale. Total plant capacity of 60-70 million SWU may be rapidly constructed in the 1990's and early 2000's.

Building of enrichment facilities using laser isotope separation in New Mexico appears to be compatible with the restrictions of New Mexico's limited water supply and lack of large excess electrical power generating capability. An enrichment facility in the state would bring jobs and money to the state. It would complement the production of yellowcake in New Mexico.

It does not appear to be too early time-wise to begin efforts to encourage the federal government to consider New Mexico as a site for a laser isotope type of enrichment plant. Mechanisms for encouraging federal interest in such a program need to be set up. Specific sites and allocation of power resources need to be investigated. Coupling the enrichment plant with a fuel fabrication facility also needs to be investigated.

Spent Fuel Reprocessing

Lasers can be used not only to obtain a more efficient enrichment process, but also to improve present spent fuel rod processing methods.

Processing of spent fuel rods reduces the new uranium ore and the enrichment needs. In LWR's as presently operated, reprocessing and recovery of the fissionable materials compared with non-reprocessing reduces the consumption of natural uranium by 32% and the separative work by 24%.

Experiments have been performed which indicate that lasers can be used in the reprocessing plants to obtain the correct valence state for the desired isotopes, in order to achieve clean separations between those materials to be extracted and those materials to be left in solution. This is particularly important in reducing waste volumes and also Pu and U contamination of wastes. It is also desirable to extract the fissionable materials as quickly as possible as radiation damage occurs in the solvent extraction process resulting in undesirable side effects. It would appear urgent to continue work on investigating the use of lasers in fuel reprocessing to recover the fissionable material.

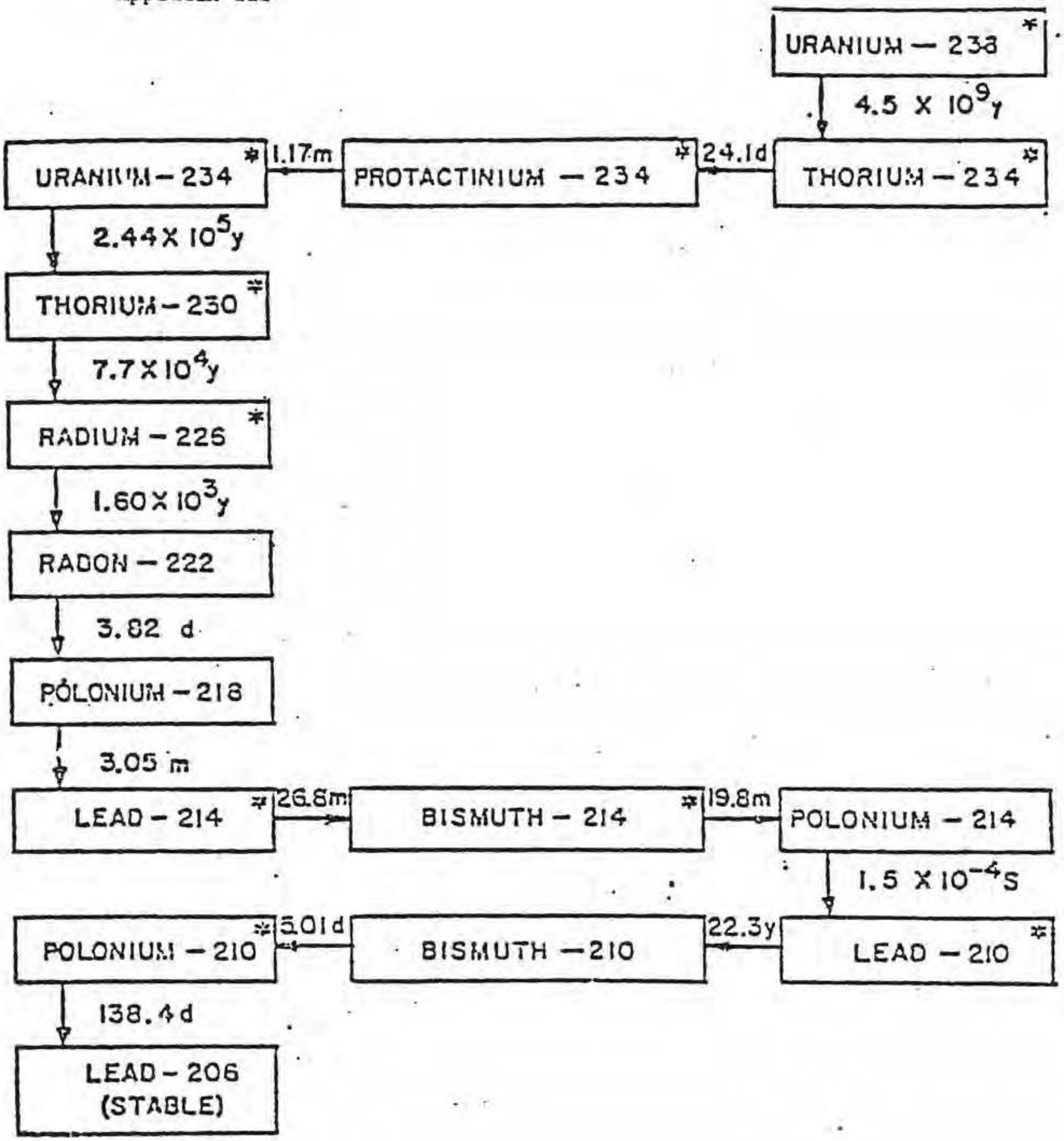
Lasers may also be useful in extracting other desired isotopes from spent reactor fuel. For example, spent fuel contains several elements which are useful as catalysts. Some radioactive isotopes can be used as heat sources, for sterilization, cancer treatment, and basic research.

Today there are available lasers to produce all wave lengths from the infrared to the ultraviolet. These selected wave lengths can be used as mentioned previously to induce desired valence states, to split apart molecules, to excite a particular atom or molecule to higher energy so that it can be separated through use of electromagnetic fields. There seem to be endless possibilities for using lasers to extract other desired isotopes besides fissionable isotopes from nuclear waste. These possibilities also need to be actively investigated in the laboratory.

Any state which accepts a radioactive waste disposal site may desire to have a fuel reprocessing, enrichment and fabrication facility associated with the site. Such an interconnected complex would give employment opportunities to people living in the region. An interconnected complex would also have the advantage of greater safety and security.

It may be to the interest of New Mexico to try and obtain an enrichment facility and a fabrication plant in the state. At the same time, the state may wish to support research on better fuel reprocessing techniques such as use of laser isotopes, so that the valuable materials contained in spent fuel can be recovered.

Appendix III



NOTE:
VERTICAL DIRECTION REPRESENTS ALPHA DECAY. HORIZONTAL DIRECTION INDICATES BETA DECAY. TIMES SHOWN ARE HALF LIVES. ONLY THE DOMINANT DECAY MODE IS SHOWN.
*ALSO GAMMA EMITTERS

RADIOACTIVE DECAY CHAIN OF URANIUM 238

Appendix IV

Maximum Permissible Concentrations (MPC) of Some Radionuclides In Air and Water.

		MPC $\frac{\mu Ci}{ml}$ (uncontrolled area)	
Radionuclide (insolu~~a~~ble)		Air	Water
Ra-226	uranium daughters	2×10^{-12}	3×10^{-5}
Th-230	uranium daughters	3×10^{-13}	3×10^{-5}
Po-210	uranium daughters	7×10^{-12}	3×10^{-5}
Pb-210	uranium daughters	8×10^{-12}	2×10^{-4}
Bi-210	uranium daughters	2×10^{-10}	4×10^{-5}
Pu-239		1×10^{-12}	3×10^{-5}
Radionuclide (solu~~a~~ble)			
Ra-226	uranium daughters	3×10^{-12}	3×10^{-8}
Th-230	uranium daughters	8×10^{-14}	2×10^{-6}
Po-210	uranium daughters	2×10^{-11}	7×10^{-7}
Pb-210	uranium daughters	4×10^{-12}	1×10^{-7}
Bi-210	uranium daughters	2×10^{-10}	4×10^{-5}
Pu-239		6×10^{-14}	5×10^{-6}

Appendix V
Water Right Requests of Uranium Companies Submitted to the State of New Mexico

Company	Date Filed	Amount Acre-ft./year	Number of Discharge Points	Location Proposed Discharge Points	Depth (feet)	Comments
Phillips Petroleum Co.	December 2, 1976	50,000 2,500-declared	12 proposed (mines) 16 declared sources	NW/4 NW/4 T19N R11W Sec 30 SW/4 NW/4 T19N R11W Sec 30 SW/4 SW/4 T19N R12W Sec 36 NW/4 SW/4 T19N R12W Sec 36 NW/4 NE/4 T19N R11W Sec 30 SE/4 NE/4 T19N R11W Sec 30 SW/4 SW/4 T19N R11W Sec 17 NW/4 SW/4 T19N R11W Sec 17 SE/4 NE/4 T19N R11W Sec 10 NW/4 NE/4 T19N R11W Sec 10 SE/4 NW/4 T18N R12W Sec 1 SW/4 NE/4 T18N R12W Sec 1	4500	no protest use application for exploration, shaft sinking, mining, milling, industrial use, agriculture. Public Service of New Mexico will probably use excess of Phillips' needs for the coal-fired Bisti plant.
Continental Oil	December 13, 1976	20,000	10	SW/4 NE/4 T17N R12W Sec 29 NE/4 NE/4 T17N R12W Sec 29 NW/4 NE/4 T17N R12W Sec 29 SE/W NE/4 T17N R12W Sec 29 NE/4 SE/4 T17N R13W Sec 24 NE/4 SE/4 T17N R13W Sec 24 SE/4 SE/4 T17N R13W Sec 24 SW/4 SW/4 T16N R10W Sec 7 SE/4 SW/4 T16N R10W Sec 7 NW/4 SW/4 T16N R10W Sec 7	2200	untimely protest

Appendix V (cont)

Company	Date Filed	Amount Acre-ft./year	Number of Discharge Points	Location Proposed Discharge Points	Depth. (feet)	Comments
Mobil Oil-TVA	March 18, 1977	5,000	4	T17N R12W Sec 28	2200	protested
Mobil Oil	March 18, 1977	20,000	21	T17N R13W Sec 3 T17N R13W Sec 4 T17N R13W Sec 6 T17N R13W Sec 8 T17N R13W Sec 12 T17N R13W Sec 15 T17N R13W Sec 16 T17N R13W Sec 23	2200	protested
Exxon	December 7, 1977	2350-diversion 1500-consumption	shafts and/or 104 wells	T12N R4W		protested
Kerr-McGee Nuclear	January 17, 1978	800 12 (evaportion)	mine shaft	T12N R 3W Sec 18		protested - mine presently under-going development
United Nuclear Corp.	January 17, 1978	3000	mine shafts (Dalton Pass)	T17N R14W Sec 14	2200	protested water use may include a mill
Pioneer Nuclear	February 20, 1978	12,000	mine and 12 wells	T17N R14W Sec 2	2500	protested
Mobil	April 13, 1978	225 Total 25 consumptive	in situ project	T17N R13W Sec 9	2000	approved 8/10/78 expires by 8/15/82
Gulf Mineral Resources	July 3, 1978	40	1	T15N R10W Sec 20	2310	water use for exploration, mine development

Source: State of New Mexico Natural Resources Department, Water Resources Division.